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DRIFTING VERTICAL CURRENT METER, MOORED AANDERAA THERMISTOR CHAIN, AND XBT DATA - JASIN 1978 ATLANTIS-II CRUISE (102)

by

Nancy J. Pennington
and
Robert A. Weller

October 1981

TECHNICAL REPORT

Prepared for the Office of Naval Research under Contract N00014-76-C-0197; NR 083-400 and for the National Science Foundation under Grant OCE 77-25803.

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WOODS HOLE, MASSACHUSETTS 02543

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Approved for Distribution: Valentine Worthington
Valentine Worthington, Chairman
Department of Physical Oceanography

Abstract

The report presents summaries of three data sets taken at and in the vicinity of the oceanographic moorings deployed in the 1978 Joint Air-Sea Interaction Project (JASIN). The data sets are: (1) the temperature, pressure and vertical motion records from the freely drifting Vertical Current Meters (VCMs) deployed from the ATLANTIS II, (2) the temperature data from the Aanderaa thermistor chains on W.H.O.I. mooring 653, designated as JASIN mooring W3, and (3) the expendable bathythermograph (XBT) data collected from the ATLANTIS II while participating in the JASIN Project.

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PREFACE

This report is the fourth and last in the JASIN (Joint Air-Sea Interaction project) data series. The other reports are:

Report #	WHOI #	Authors	Subject
1	79-42	Pennington, N. and M. G. Briscoe	CTD Profiles
2	79-43	Briscoe, M. G., C. Mills, R. Payne and K. Peal	Meteorological measurements
3	79-65	Tarbell, S., M. G. Briscoe and R. Weller	Current meter data

ACKNOWLEDGEMENTS

The W.H.O.I. buoy group designed, prepared, deployed, and recovered the moorings. Jerry Dean was responsible for the preparation and use of the Vertical Current Meters. Rick Trask analyzed the failures of the Aanderaa thermistor chain recorders and, after JASIN, came up with solutions to those failures. We thank Mary Ann Lucas for her typing and editing of this report.

This work has been supported by ONR Contract N00014-76-C-0197, NR083-400 and by NSF Grant OCE77-25803.

INTRODUCTION

The Joint Air-Sea Interaction project (JASIN) was a multi-national program initiated in 1966 by the Royal Meteorological Society (U.K); the major field experiment was conducted in July to September 1978 northwest of Scotland in the northern end of Rockall Trough. Some fourteen ships, four aircraft, nine countries, and sixty principal investigators participated. Pollard (1978) provides an overview of the JASIN 1978 experiment.

Work done by participants from the Woods Hole Oceanographic Institution included the deployment of moored current meters and meteorological instrumentation (see Tarbell, et. al., 1979), hydrographic work from the ATLANTIS II (A-II) (see Pennington and Briscoe, 1979), shipboard meteorological measurements (see Briscoe, et. al., 1979), and temperature measurements from moored Aanderaa thermistor chains, XBTs, and the freely drifting Vertical Current Meters (VCMs). This data report contains a description of the Aanderaa thermistor chain, XBT, and VCM components of the JASIN work and summaries of the three data sets.

Figure 1 shows the overall JASIN area and the Fixed Intensive Array (FIA) where most of the JASIN moorings were located. The FIA is detailed in the lower left of Figure 1. Mooring K1 from the Institut für Meereskunde (Kiel, F. R. Germany), moorings B1-B4 from Oregon State University, and mooring H2 from NOAA/PMEL in Seattle are shown for reference.

The Vertical Current Meters were deployed to track the horizontal velocity field in the vicinity of the moorings and to provide a direct measurement of the vertical component of velocity and of temperature as they drifted. The Aanderaa TR-1 thermistor chain was deployed to investigate the vertical structure of the temperature variability at the location of mooring W3. The XBTs were taken to collect information on the spatial variability of the temperature field in the vicinity of the FIA. This data report is divided into three parts. Parts 1, 2, and 3 cover the Vertical Current Meters, Aanderaa thermistor chains, and XBTs, respectively.

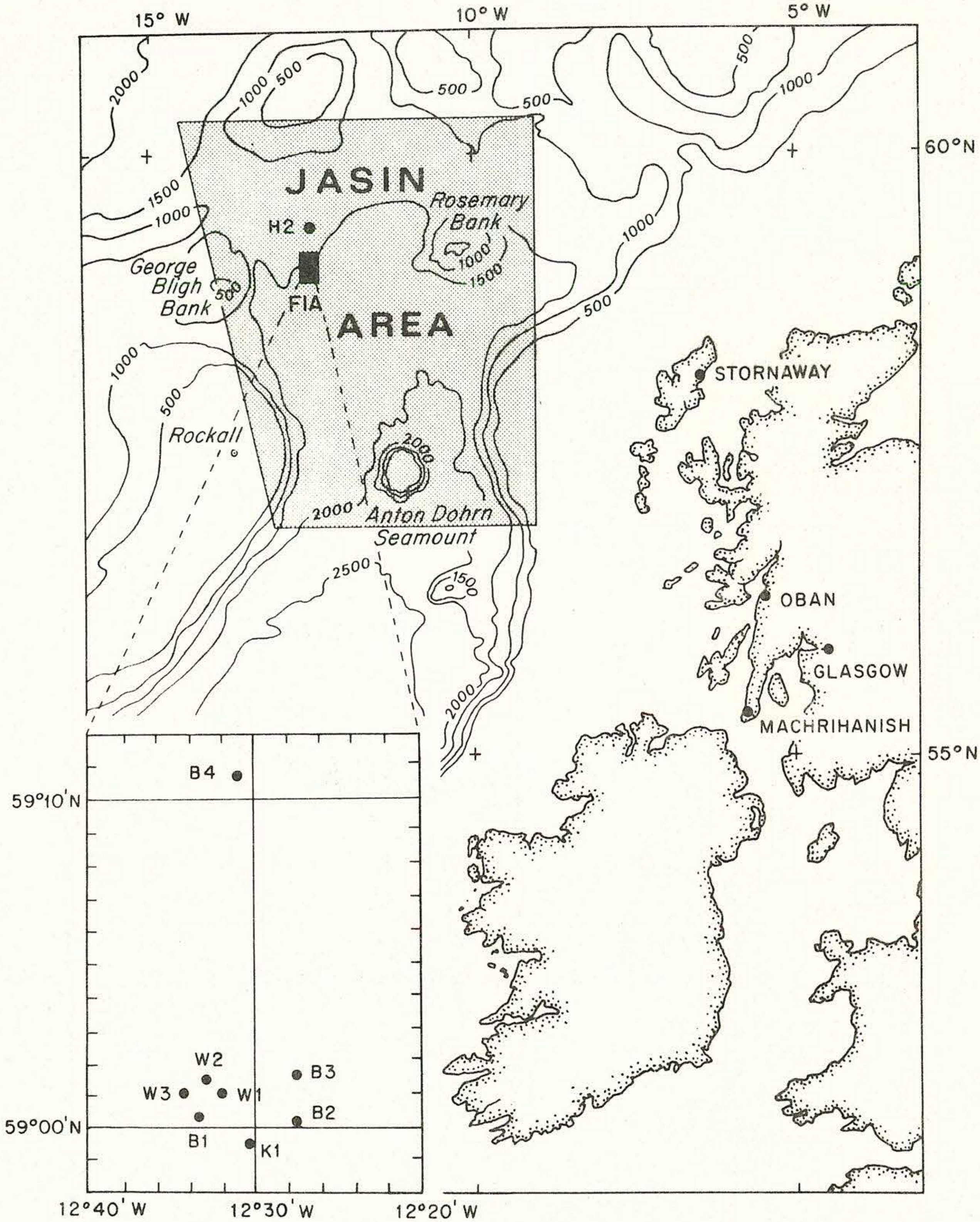


FIGURE 1: Chart of JASIN Area

Part I.

Vertical Current Meters

Vertical Current Meters (VCM)

The VCMs are neutrally buoyant, free-floating instruments which are ballasted to sink to a predetermined depth. While floating at that depth the instrument makes measurements of the vertical velocity relative to itself, of pressure, and of temperature. Three instruments, VCM #1, VCM #2, and VCM #5, were deployed during JASIN in a total of ten different drops. The area within which the floats drifted is shown in Figure 2.

Relative vertical current is sensed by an array of vanes mounted axially around the float, Fig. 3. Because the float compressibility is less (about 1/2) than that of the water, vertical motions in the water generate relative vertical flow past the vanes causing the entire float to rotate. This rotation is sensed relative to an internal compass. The sum of the pressure change (float vertical motion) and the rotation of the float (flow relative to the float) is a measure of total vertical water displacement, with a resolution of about 2 cm. The temperature measurement is accurate to about 0.010°C. On some VCMs (VCM-DT), temperature difference was measured by thermistors placed 1 m apart along the outside of the pressure housing. The accuracy is about .002°C (Dean, 1979). The calibration of float rotation to vertical displacement was done using a plot of relative displacement, proportional to float turns, vs. pressure as the instrument sank during deployment. From the slope of this curve the calibration constant was determined.

The VCM floats used in JASIN were weighed in a fresh water tank at Woods Hole and ballasted to be neutrally buoyant at a selected surface temperature and salinity standard of 11.0°C and 35.32°/₀₀. The ballast was then adjusted for depth based on in situ temperature and salinity at the desired depth. The VCM float constants are approximately

0.0804 gm/meter	ballast for depth,
0.332 gm/°C	temperature correction,
27 gm/°/₀₀	salinity correction.

A summary of desired depths and actual depths is included in Table 1.

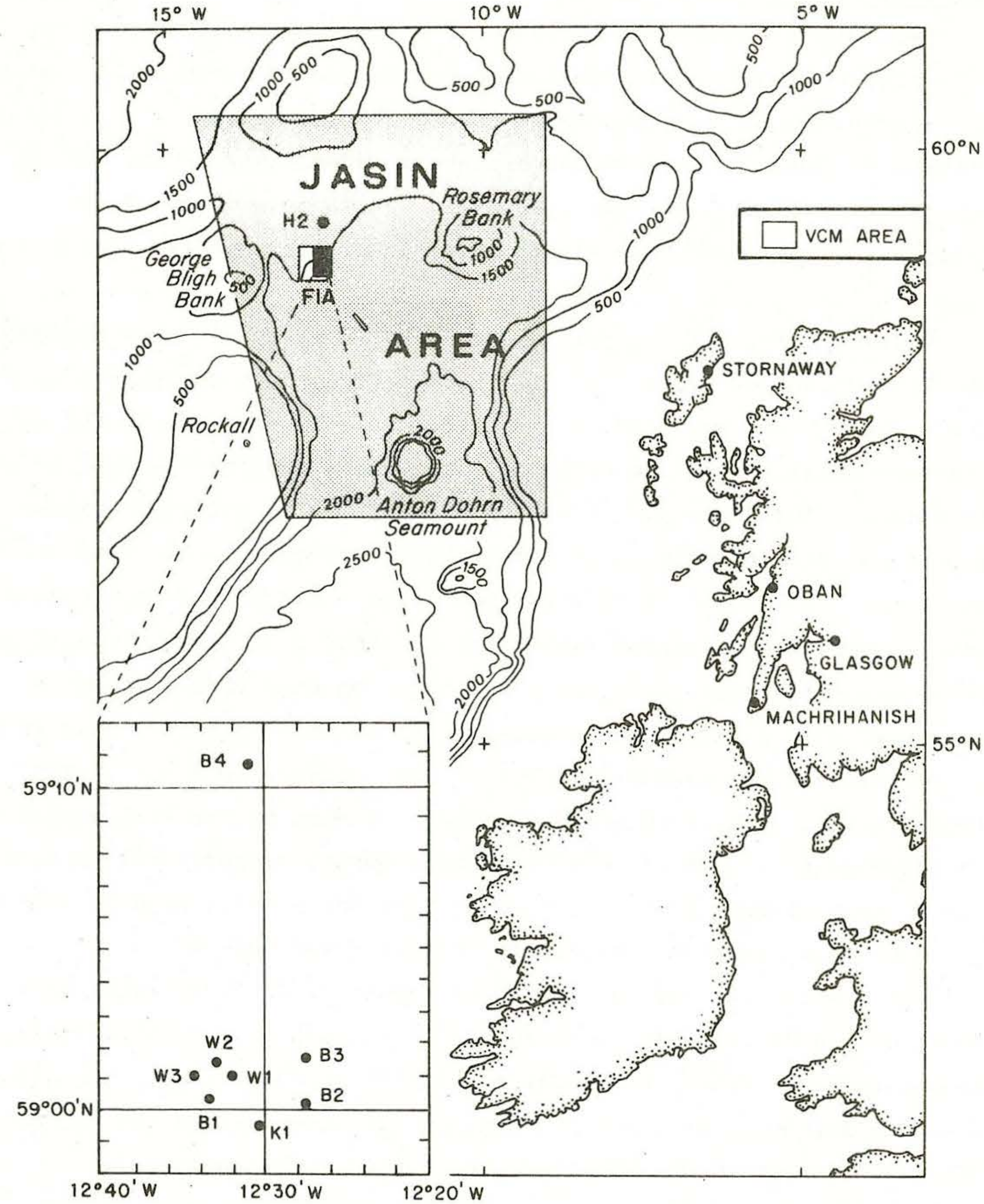


Figure 2. White Areas -- VCM Drops

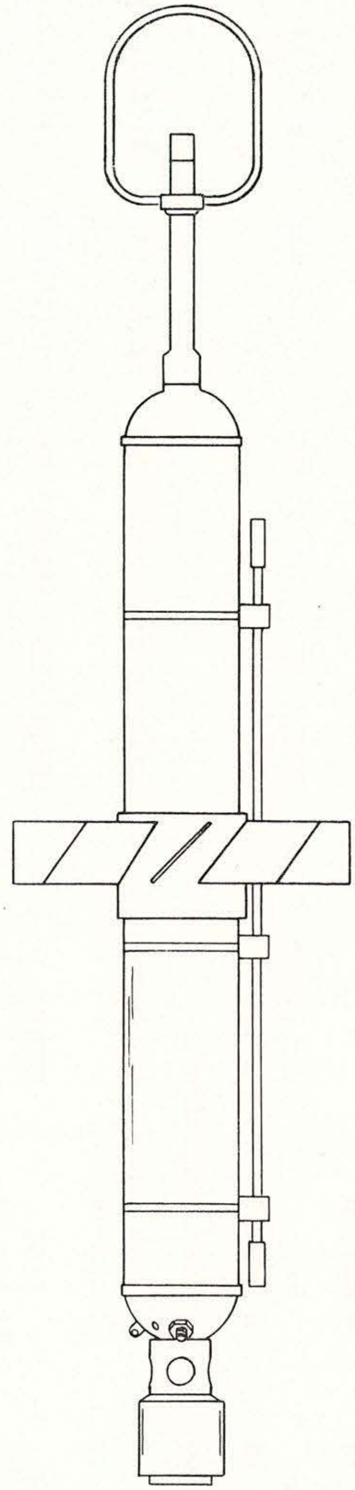


Figure 3. Scaled side view of the vertical current meter (VCM) showing its orientation when neutrally buoyant. The overall length of the instrument from recovery bail (top) to the transducer (bottom) is 2.2 meters. Vertical motion is sensed by eight inclined vanes shown at the mid-point of the cylinder.

TABLE 1.
ATLANTIS-II-102
JASIN 1978
VERTICAL CURRENT METER (VCM) SUMMARY SHEET

VCM DROP #	NOM. DEPTH	DATA HOURS	START TIME	END TIME	COMMENT	DEPLOYMENT POSITION LAT.	DEPLOYMENT POSITION LONG.	RETRIEVAL POSITION LAT.	RETRIEVAL POSITION LONG.
1	213 m	5.0	2250 28 Jul 78	0350 29 Jul 78	VCM #2(DT)	59°02'.69N	12°26'.72W	59°04'.07W	12°30'.41W
2	113 m	26.2	1208 1 Aug 78	1420 2 Aug 78	VCM #2(DT)	59°00'.47N	12°32'.81W	59°04'.14N	12°47'.15W
3	83 m	32.4	1134 3 Aug 78	2000 4 Aug 78	VCM #2(DT)	58°41'.28N	12°04'.77W	58°34'.70N	11°47'.72W
4	90 m	12.8	1230 5 Aug 78	0113 6 Aug 78	VCM #2(DT)	59°01'.77N	12°36'.03W	59°01'.65N	12°49'.42W
5	VCM #1 lost on 6 Aug 78 during recovery operations								
6	83 m	18.3	1507 8 Aug 78	0927 9 Aug 78	VCM #2(DT)	59°00'.44N	12°21'.20W	59°06'.01N	12°27'.54W
7	75 m	45.8	1409 9 Aug 78	1154 11 Aug 78	VCM #5 INTERCOMPARISON	58°57'.60N	12°30'.88W	59°11'.62N	12°53'.24W
8	76 m	47.5	1408 9 Aug 78	1335 11 Aug 78	VCM #2(DT)	58°57'.60N	12°30'.88W	59°11'.72N	12°54'.88W
9	68 m	39.8	0107 12 Aug 78	1703 13 Aug 78	VCM #5 INTERCOMPARISON	58°58'.50N	12°28'.27W	59°09'.31N	12°44'.71W
10	70 m	39.9	0106 12 Aug 78	1701 13 Aug 78	VCM #2(DT)	58°58'.50N	12°28'.27W	59°09'.31N	12°44'.71W
		267.7							

The VCM includes an AMF acoustic release receiver and a release of W.H.O.I. design. On command from the ship, or on preset command from an internal timer, the float drops a 900 gm weight and returns to the surface for recovery. A flashing light turns on at release time, and the "ping" rate doubles to confirm release. Four hydrophones, two on each side of the ship, were streamed for the purpose of tracking the VCMs. During JASIN, however, the need for the ATLANTIS II to participate during parts of every day in other experimental work made detailed tracking of the floats impossible. The acoustic tracking capability and the light simplify finding the float on the surface in spite of its low profile in the water. Nine recoveries were made under a variety of weather and light conditions during this cruise. An instrument was lost on the fifth drop during recovery operations.

For further references on VCM design and performance, see Burt et al (1974), Dorson (1974), and Voorhis (1971).

Data recorded each 16 seconds on a digital data cassette recorder include average temperature, as temperature difference (in the VCM-DT models), and pressure for the record interval; accumulated turns at the time of recording; and total number of record intervals since a reference time zero. Preliminary data processing aboard ship consists of reading the data cassette and producing a computer compatible 9-track data record. Data from the 9T tape could be listed and plotted on the Calcomp in engineering units for an early check on quality and a preliminary scientific evaluation.

Table 1 summarizes the VCM performance. There were 11 days, 37 hours of good data records. Drop 6 could not be decoded. Drop 1 was a short duration test deployment. Drop 5 ended with the loss of VCM #1 during recovery. Drops 2, 4, 7, 8, 9 and 10 were conducted in the vicinity of mooring W2, and drop 3 was conducted to the southeast of mooring W2 (Fig. 4). The floats deployed near W2 drifted to the northwest or west. Drops 7 and 8 and drops 9 and 10 were simultaneous deployments of two floats. The float deployed during drop 3 drifted to the southeast.

Figures 5-12 give time series of pressure, temperature, tdif., and float rotation, labelled turns. The floats' pressure record shows that the instruments oscillated with an amplitude of upwards of 20 meters. Vertical water displacement time series, calculated from the pressure and rotation records and averaged over 12 minute intervals, are shown in Fig. 13. Upward displacement of the water was observed by the VCMs deployed during JASIN.

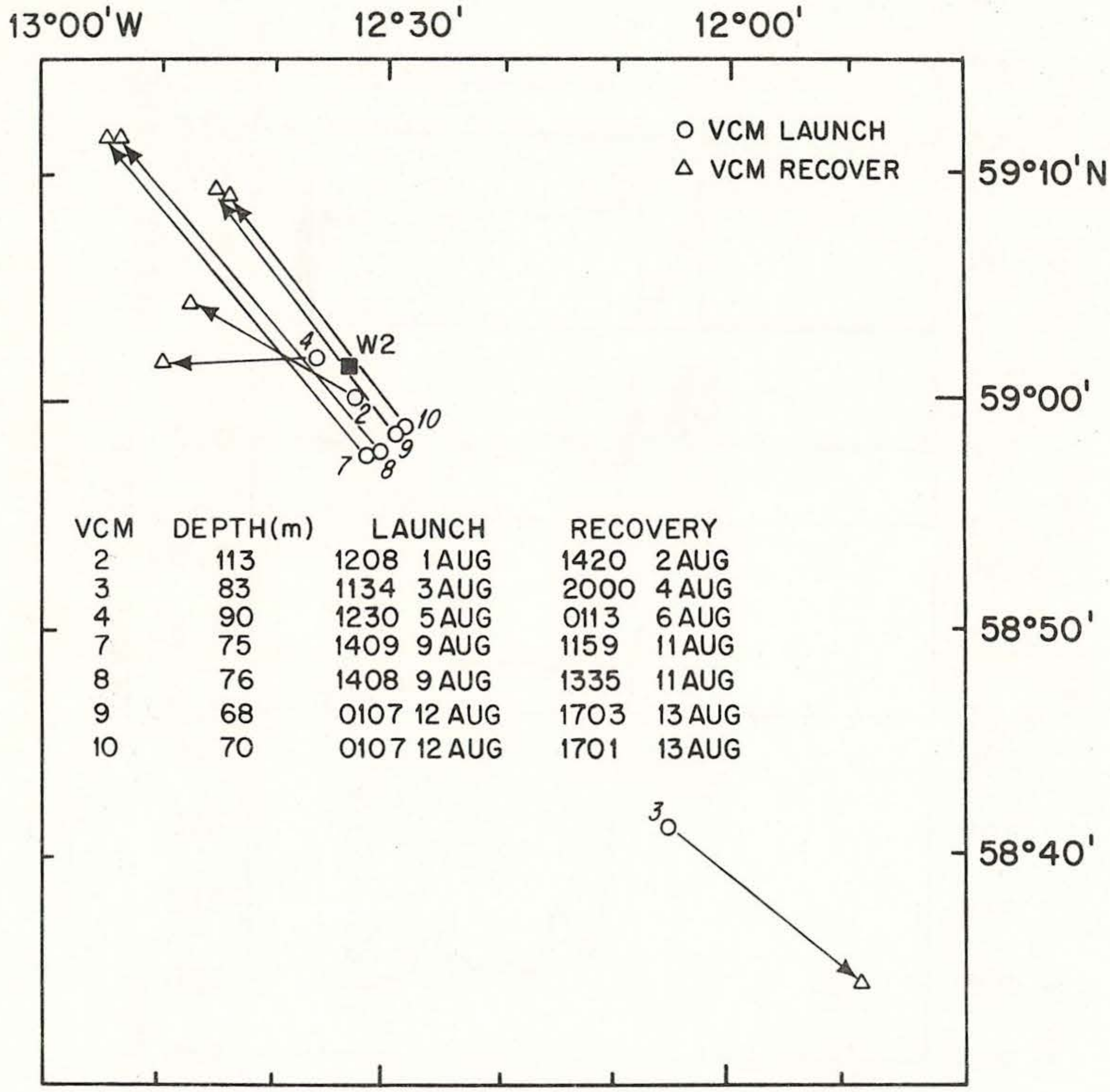


Figure 4. VCM drift patterns.

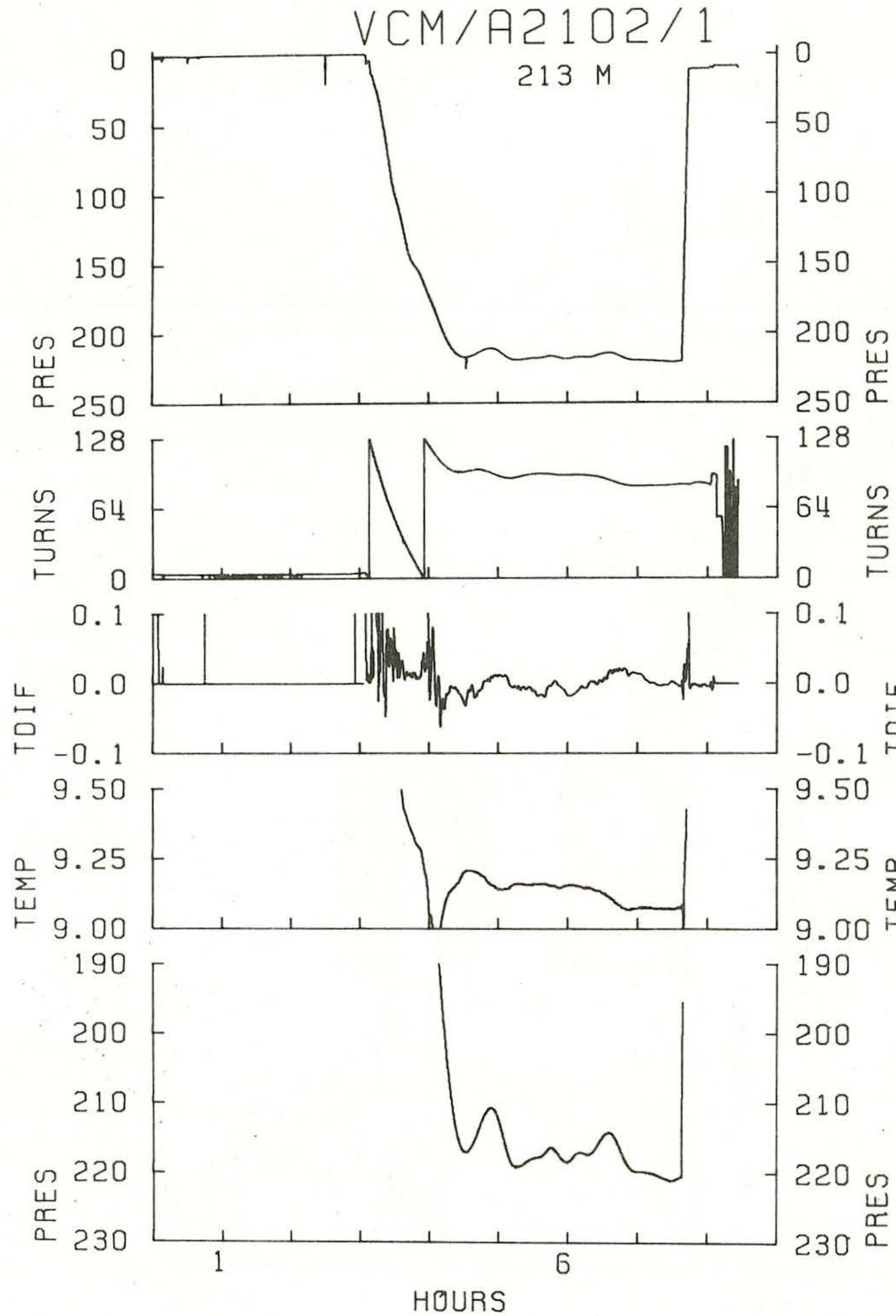

VCM/A2102/1
213 M
PRES
TURNS
TDIF
TEMP
PRES
0
50
100
150
200
250
128
64
0
0.1
0.0
-0.1
9.50
9.25
9.00
190
200
210
220
230
1
6
HOURS

Figure 5.

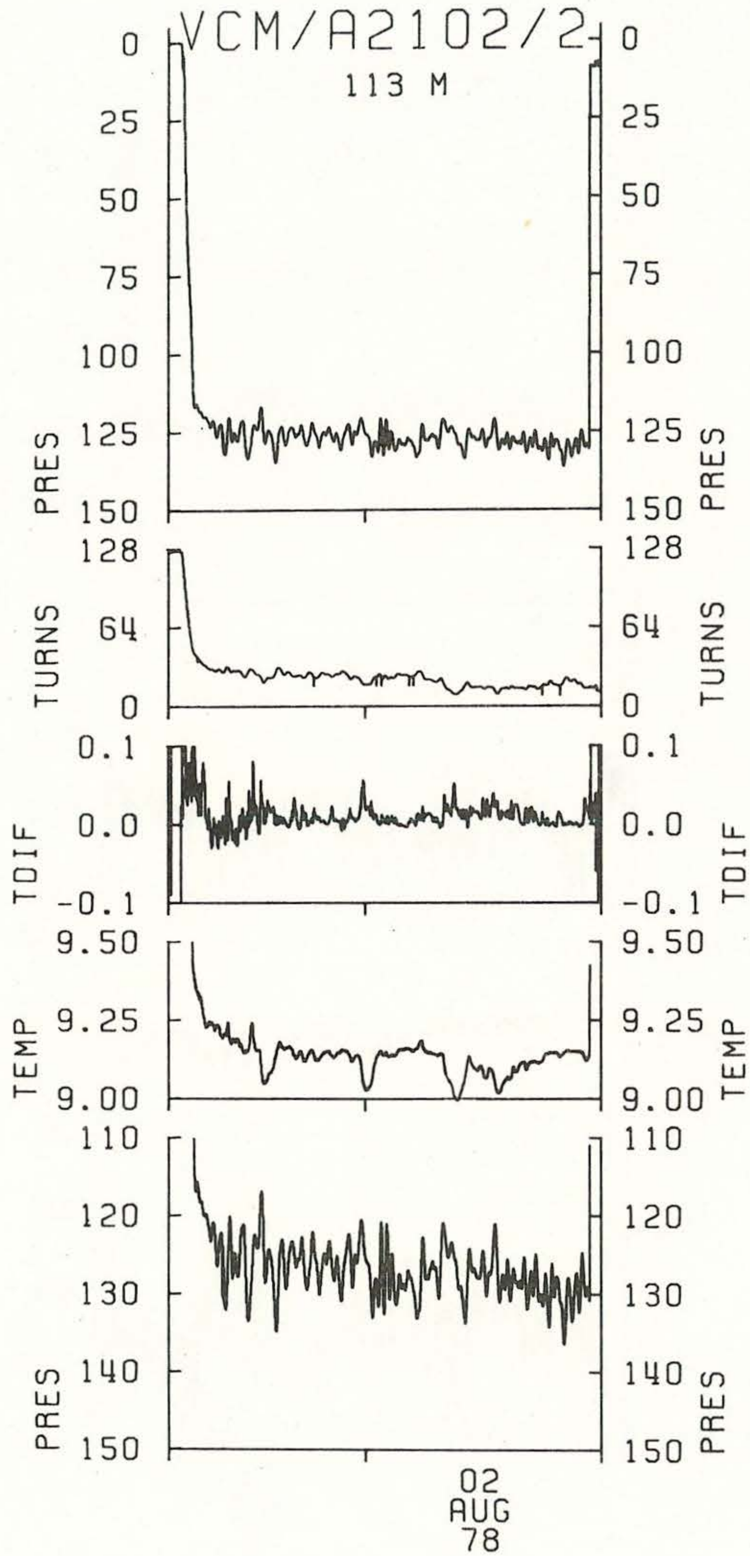
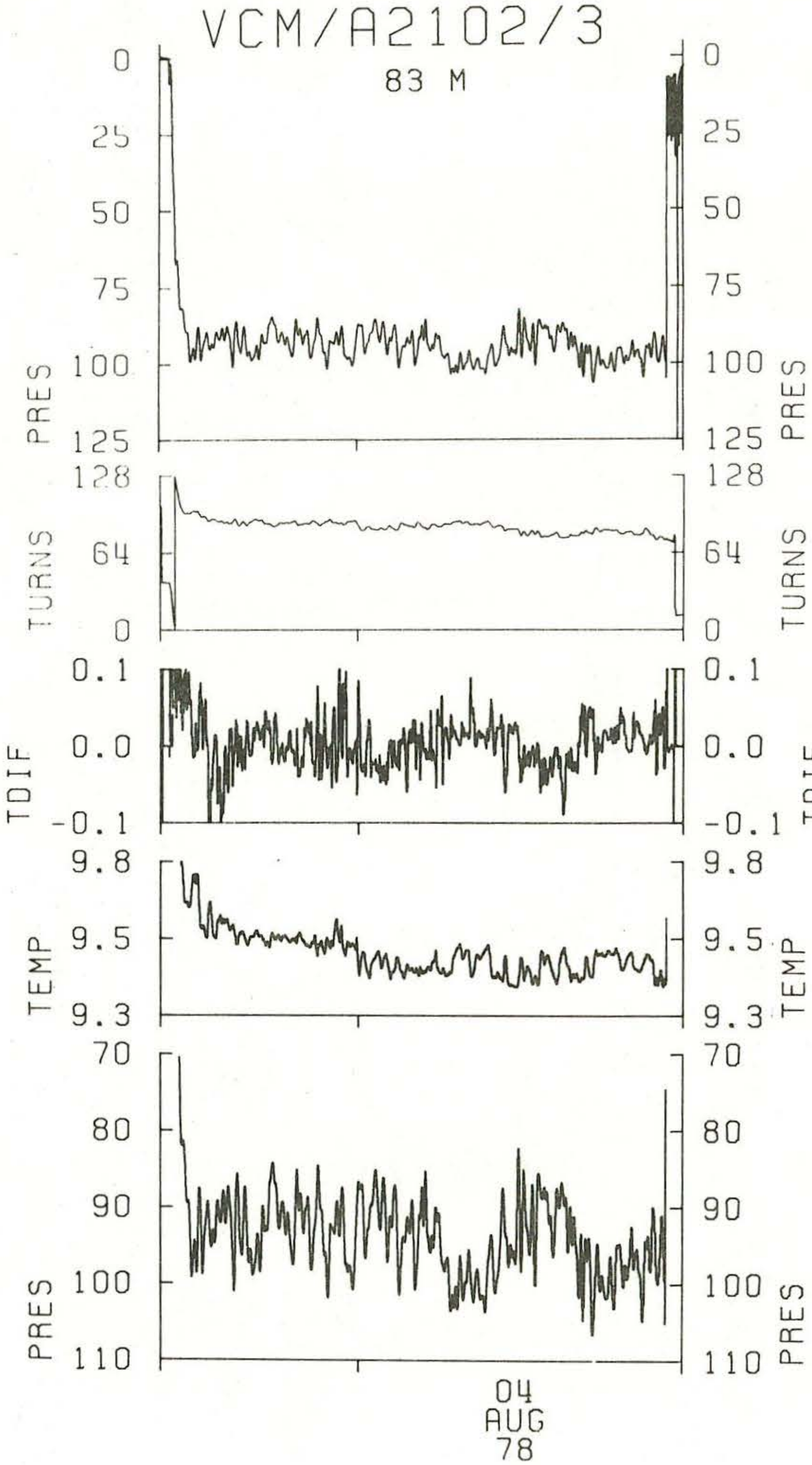

VCM/A2102/2
113 M
PRES
TURNS
TDIF
TEMP
PRES
0
25
50
75
100
125
150
128
64
0
0.1
0.0
-0.1
9.50
9.25
9.00
110
120
130
140
150
02
AUG
78

Figure 6.



VCM/A2102/3
83 M
0
25
50
75
100
125
PRES
128
64
0
TURNS
0.1
0.0
-0.1
TDIF
9.8
9.5
9.3
TEMP
70
80
90
100
110
PRES
04
AUG
78

Figure 7.

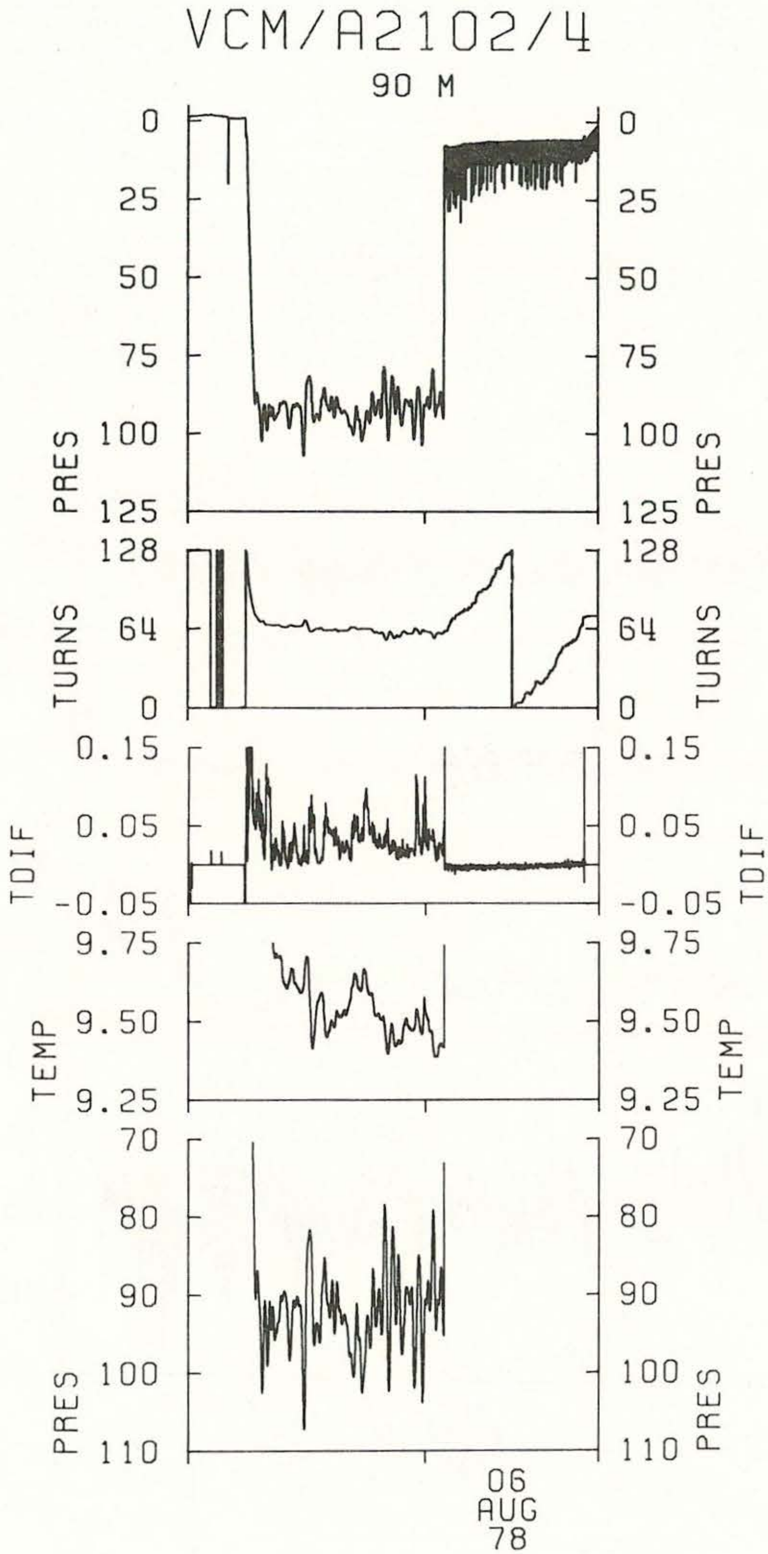

VCM/A2102/4
90 M
0
25
50
75
100
125
PRES
128
64
0
TURNS
0.15
0.05
-0.05
TDIF
9.75
9.50
9.25
TEMP
70
80
90
100
110
PRES
06
AUG
78

Figure 8.

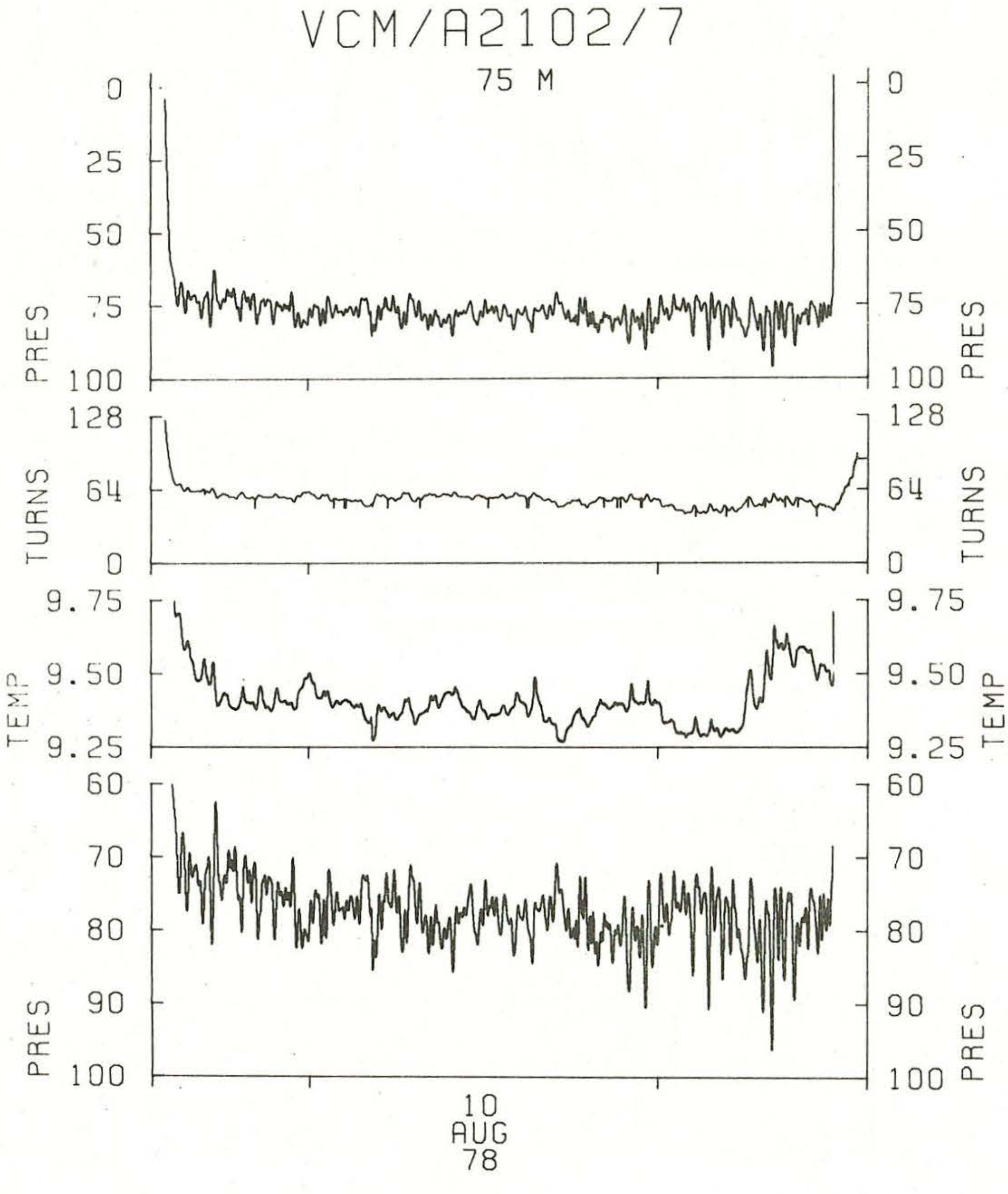
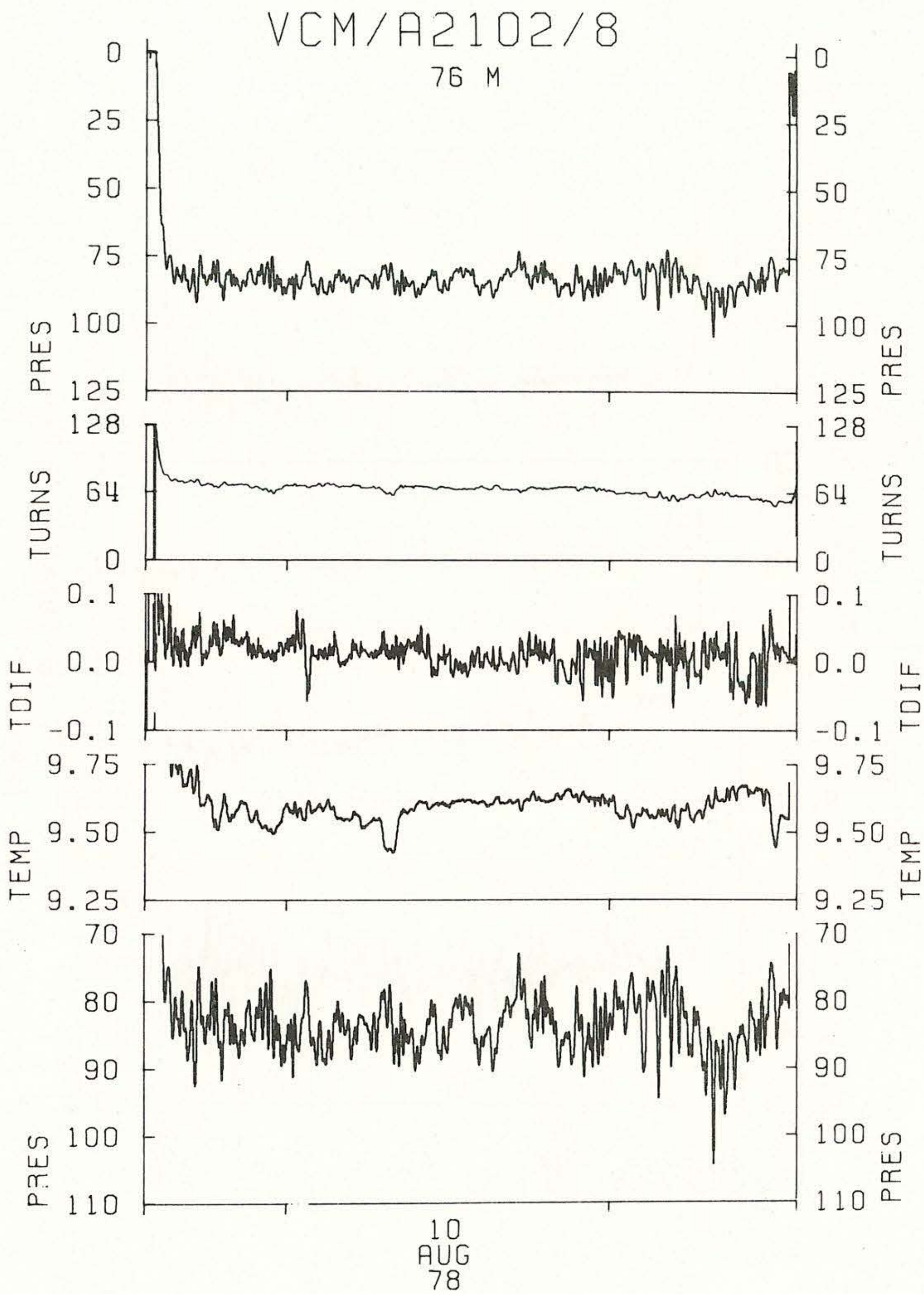
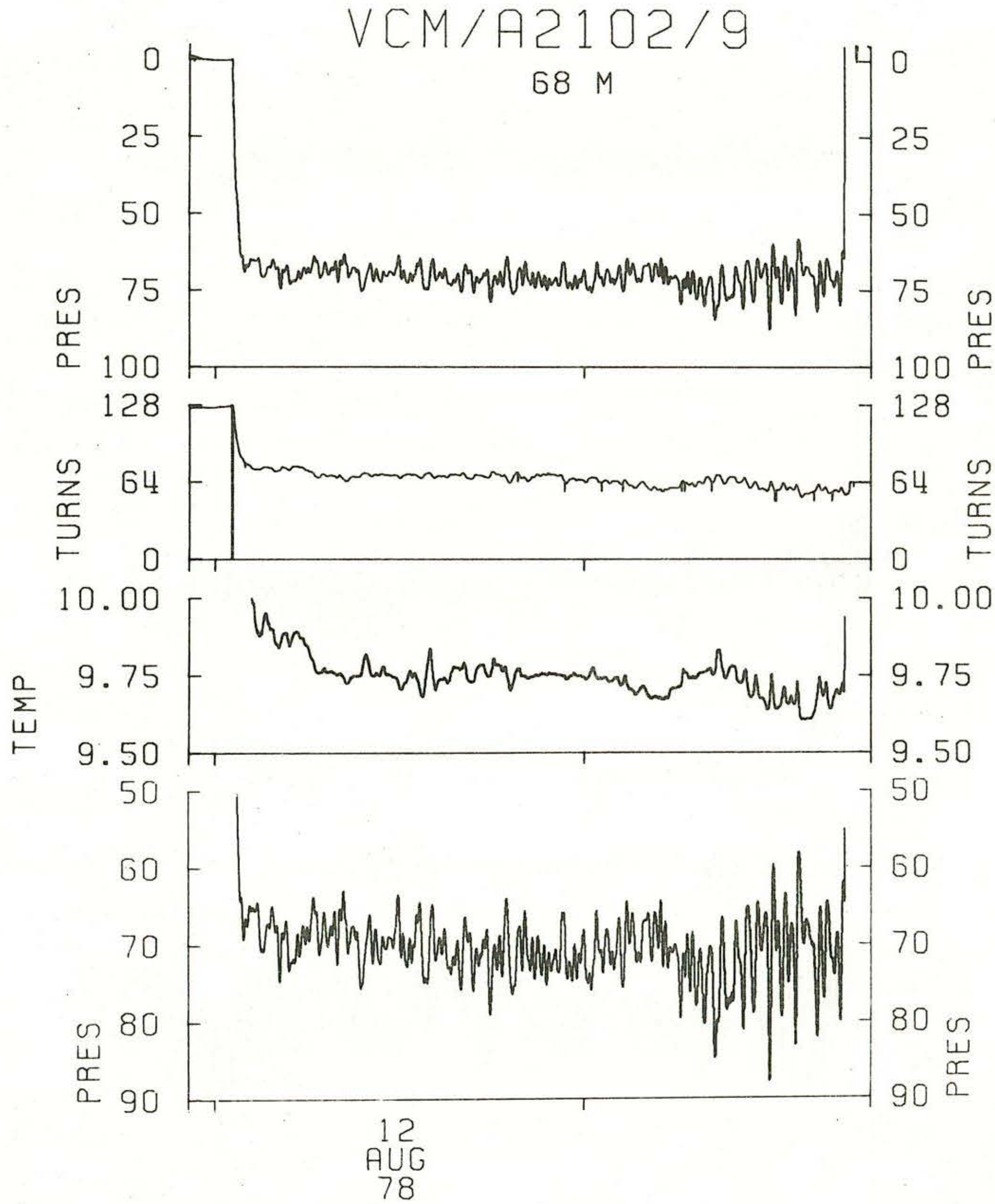

VCM/A2102/7
75 M
0
25
50
75
100
PRES
128
64
0
TURNS
9.75
9.50
9.25
TEMP
60
70
80
90
100
PRES
10
AUG
78

Figure 9.



VCM/A2102/8
76 M
PRES
TURNS
TDIF
TEMP
PRES
0
25
50
75
100
125
128
64
0
0.1
0.0
-0.1
9.75
9.50
9.25
70
80
90
100
110
10
AUG
78

Figure 10.



VCM/A2102/9
68 M
0
25
50
75
100
PRES
128
64
0
TURNS
10.00
9.75
9.50
TEMP
50
60
70
80
90
PRES
12
AUG
78

Figure 11.

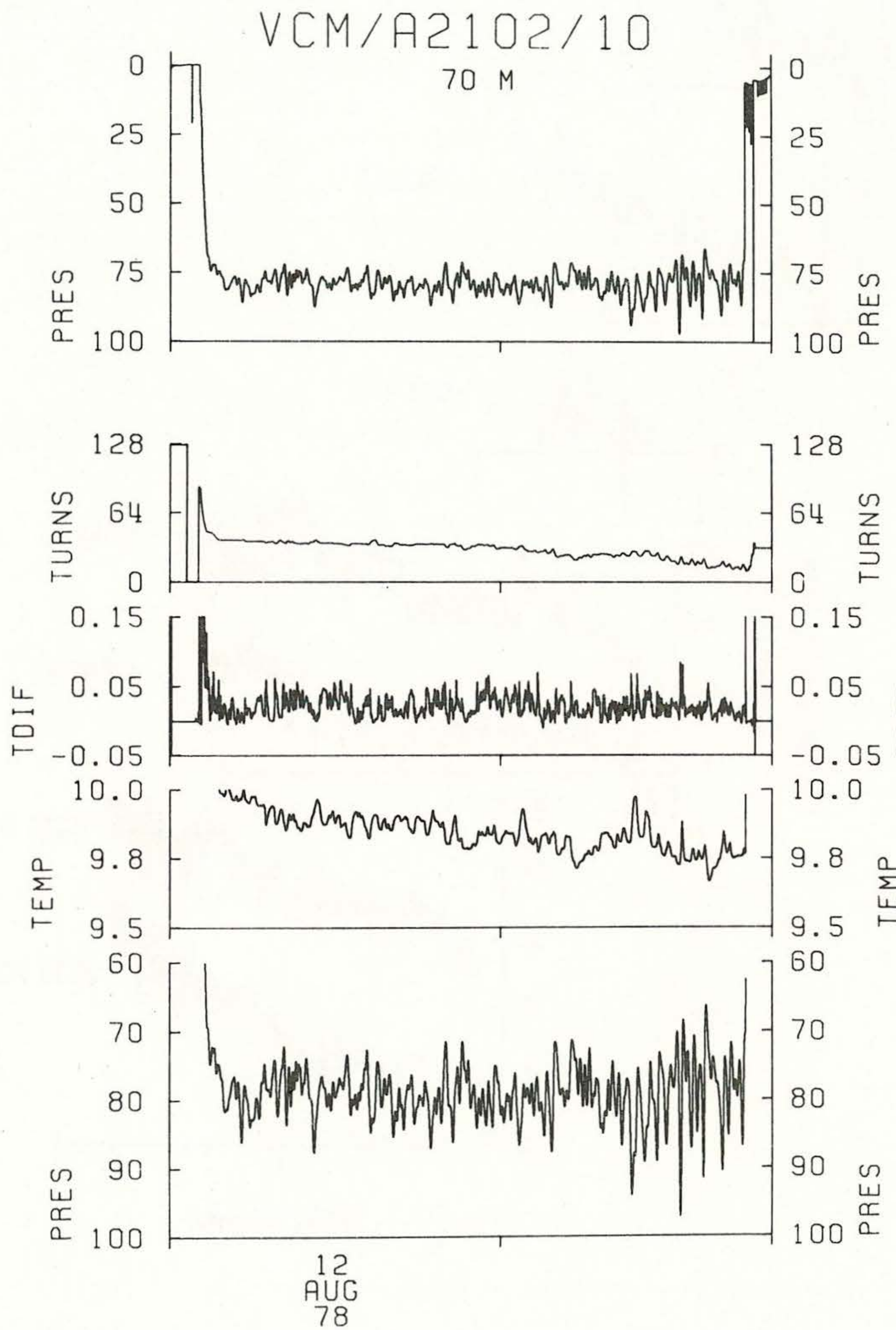


Figure 12.

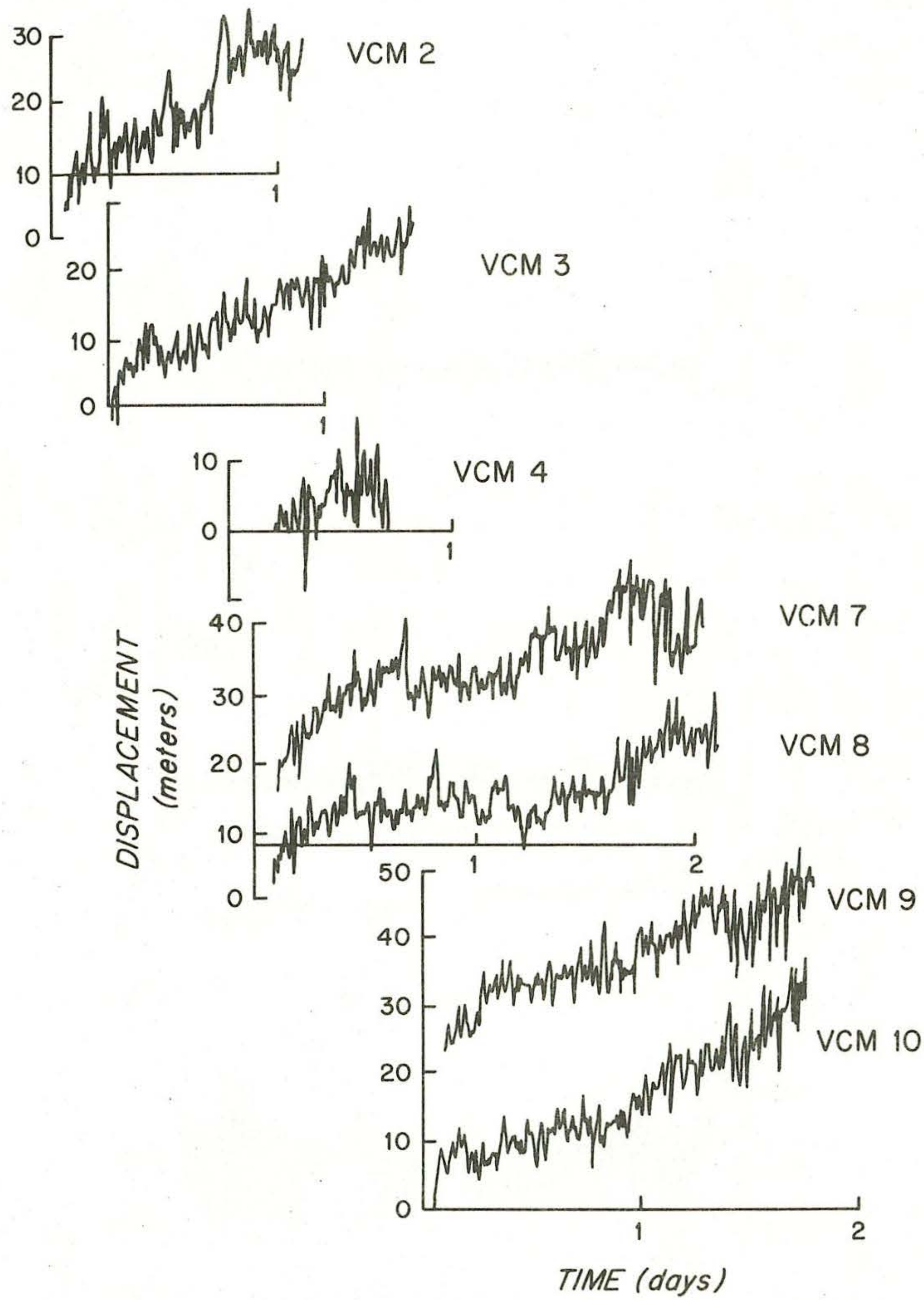


Figure 13. VCM Displacement plots.

Part II.

Aanderaa Thermistor Chain

Aanderaa Thermistor Chains

Three Aanderaa thermistor chains (TR-1) were deployed on W.H.O.I. mooring 653, identified in JASIN as mooring W3. The recording packages of the instruments were each held in a stainless steel bracket with a strength member that fastened in-line with the mooring. The thermistor chains were attached to the wire rope of the mooring with spiral shaped plastic coils (commonly used for wrapping bundles of wires together).

Two of the Aanderaa thermistor chains deployed during JASIN failed to record any data because the magnetic tape became fouled around the tape drive capstan, early in the experiment. The problem occurred because the lower take-up spool did not maintain the proper tension in the tape which allowed the tape to go slack and eventually foul. Subsequent investigations revealed that in the two instruments that failed the shaft on which the lower take-up spool turns was of an older design whereas the corresponding take-up spool had undergone modifications. When this assembly was subjected to cold temperatures, it became jammed which in turn let the tape go slack. The instrument which functioned properly during the experiment did not have this mismatch of new and old components.

The data from the one instrument that did work has been presented in two ways. First, the temperatures recorded by the thermistors (at 31, 34, 37, 40, 43, 46, 49, 52, 55, and 58 m depths, nominally) have been plotted. Second, isotherm depths (for the 13.0, 12.8, 12.6, 12.4, 12.2, 12.0, 11.8, 11.6, 11.4, 11.2, 11.0, 10.8, 10.6, 10.4, 10.2, 10.0, 9.8, 9.6, 9.4, and 9.2°C isotherms) have been plotted. In both cases the scales have been chosen to match the scales used in the Oregon State University data reports covering their JASIN thermistor chain data.

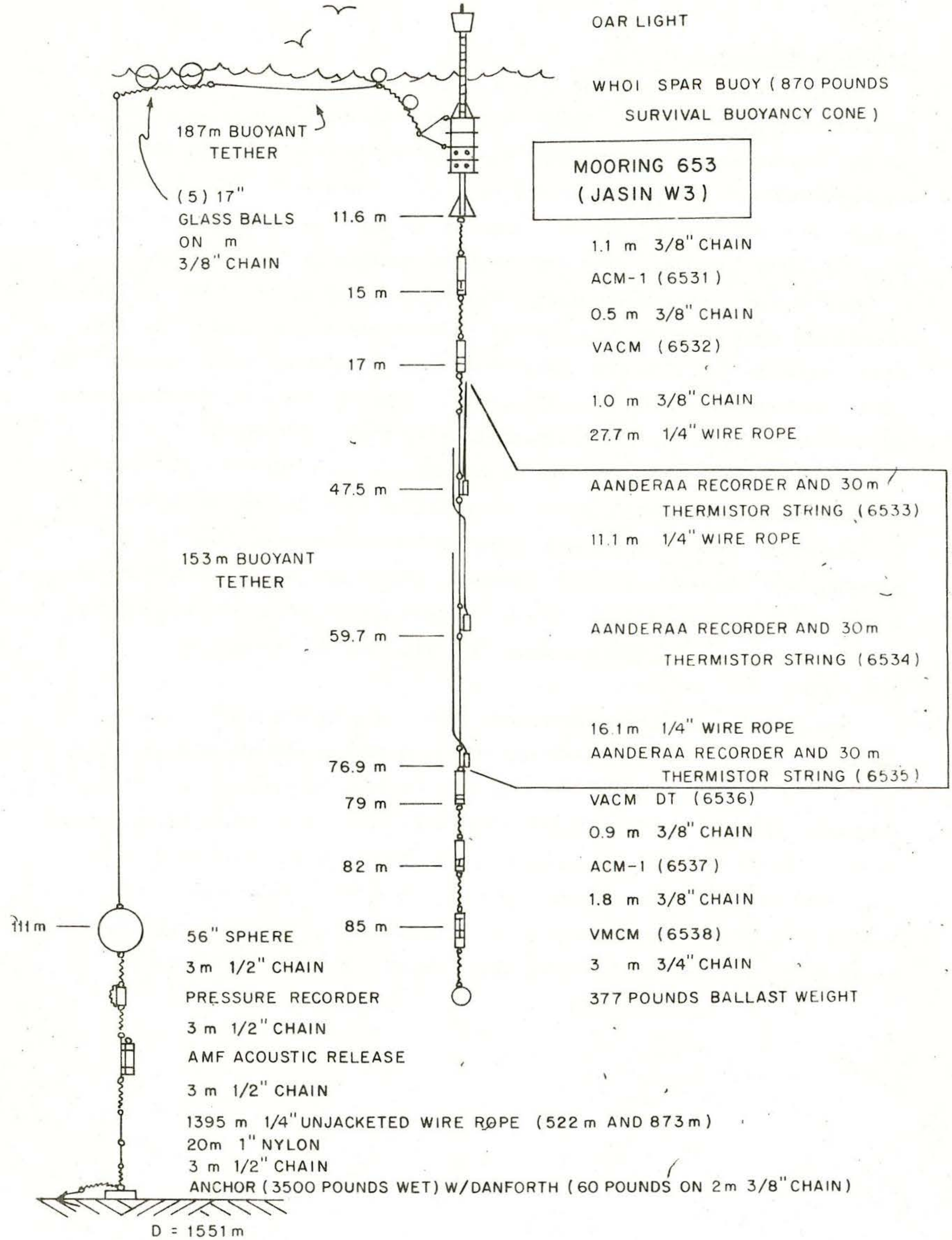

OAR LIGHT
WHOI SPAR BUOY (870 POUNDS SURVIVAL BUOYANCY CONE)
187m BUOYANT TETHER
MOORING 653 (JASIN W3)
(5) 17" GLASS BALLS ON m 3/8" CHAIN
11.6 m
1.1 m 3/8" CHAIN
ACM-1 (6531)
15 m
0.5 m 3/8" CHAIN
VACM (6532)
17 m
1.0 m 3/8" CHAIN
27.7 m 1/4" WIRE ROPE
47.5 m
AANDERAA RECORDER AND 30 m THERMISTOR STRING (6533)
11.1 m 1/4" WIRE ROPE
153 m BUOYANT TETHER
59.7 m
AANDERAA RECORDER AND 30 m THERMISTOR STRING (6534)
16.1 m 1/4" WIRE ROPE
AANDERAA RECORDER AND 30 m THERMISTOR STRING (6535)
76.9 m
79 m
VACM DT (6536)
0.9 m 3/8" CHAIN
82 m
ACM-1 (6537)
1.8 m 3/8" CHAIN
111 m
56" SPHERE
85 m
VMCM (6538)
3 m 1/2" CHAIN
3 m 3/4" CHAIN
PRESSURE RECORDER
377 POUNDS BALLAST WEIGHT
3 m 1/2" CHAIN
AMF ACOUSTIC RELEASE
3 m 1/2" CHAIN
1395 m 1/4" UNJACKETED WIRE ROPE (522 m AND 873 m)
20m 1" NYLON
3 m 1/2" CHAIN
ANCHOR (3500 POUNDS WET) W/DANFORTH (60 POUNDS ON 2 m 3/8" CHAIN)
D = 1551 m

Figure 14.

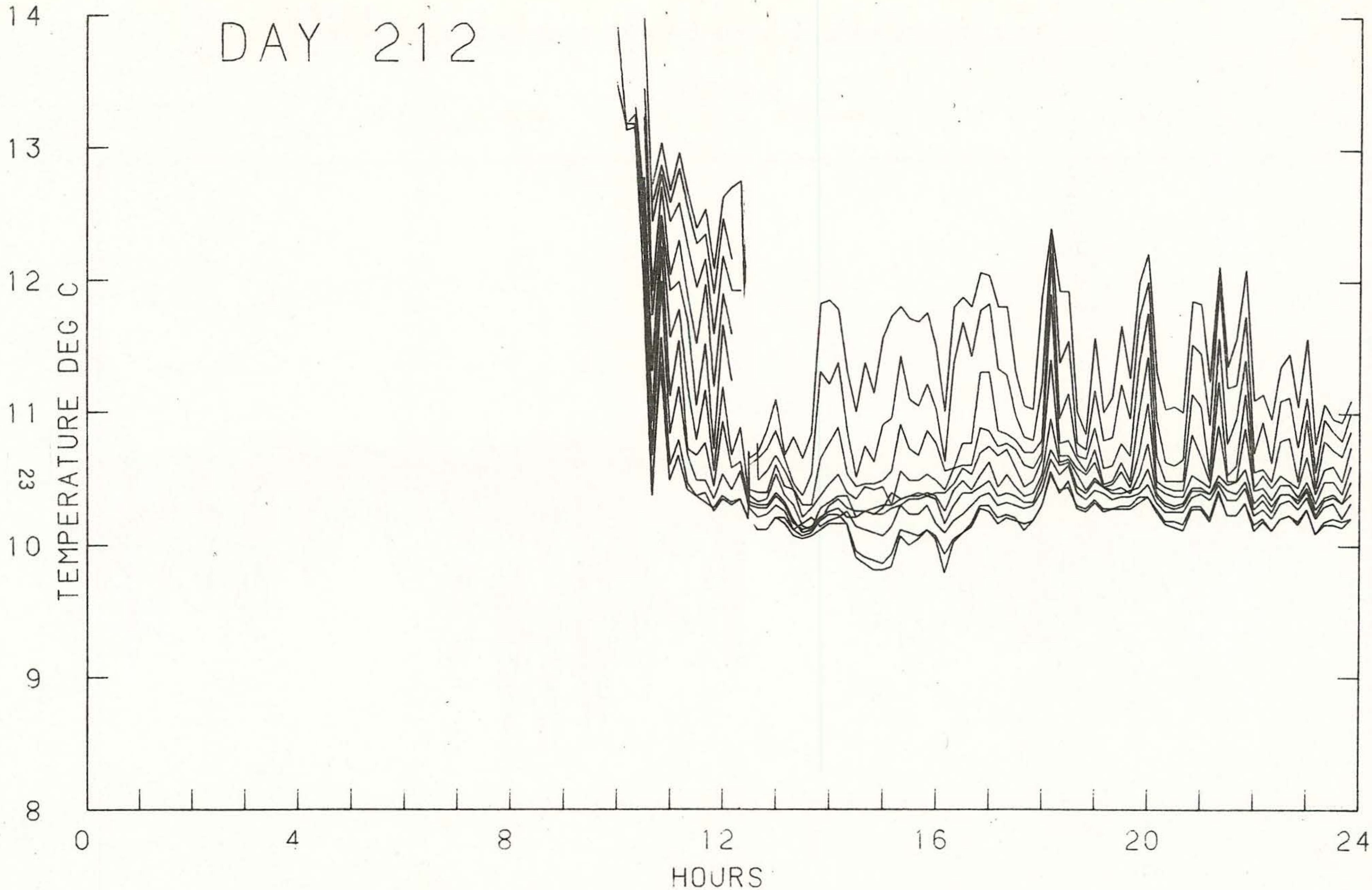
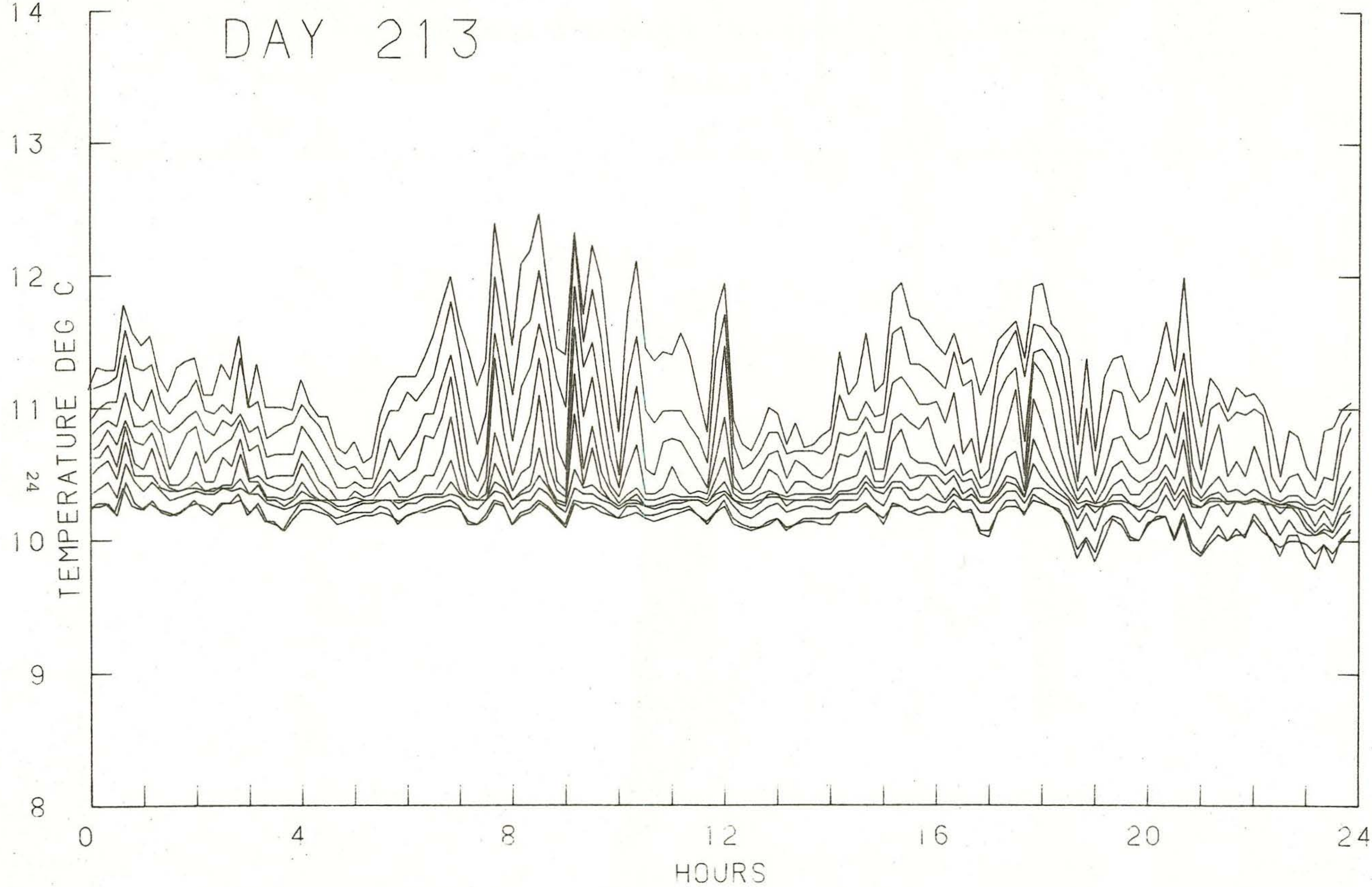


Figure 15. Temperature at 31,34,37,40,43,46,49,52,55 and 58 m (nominal depths).



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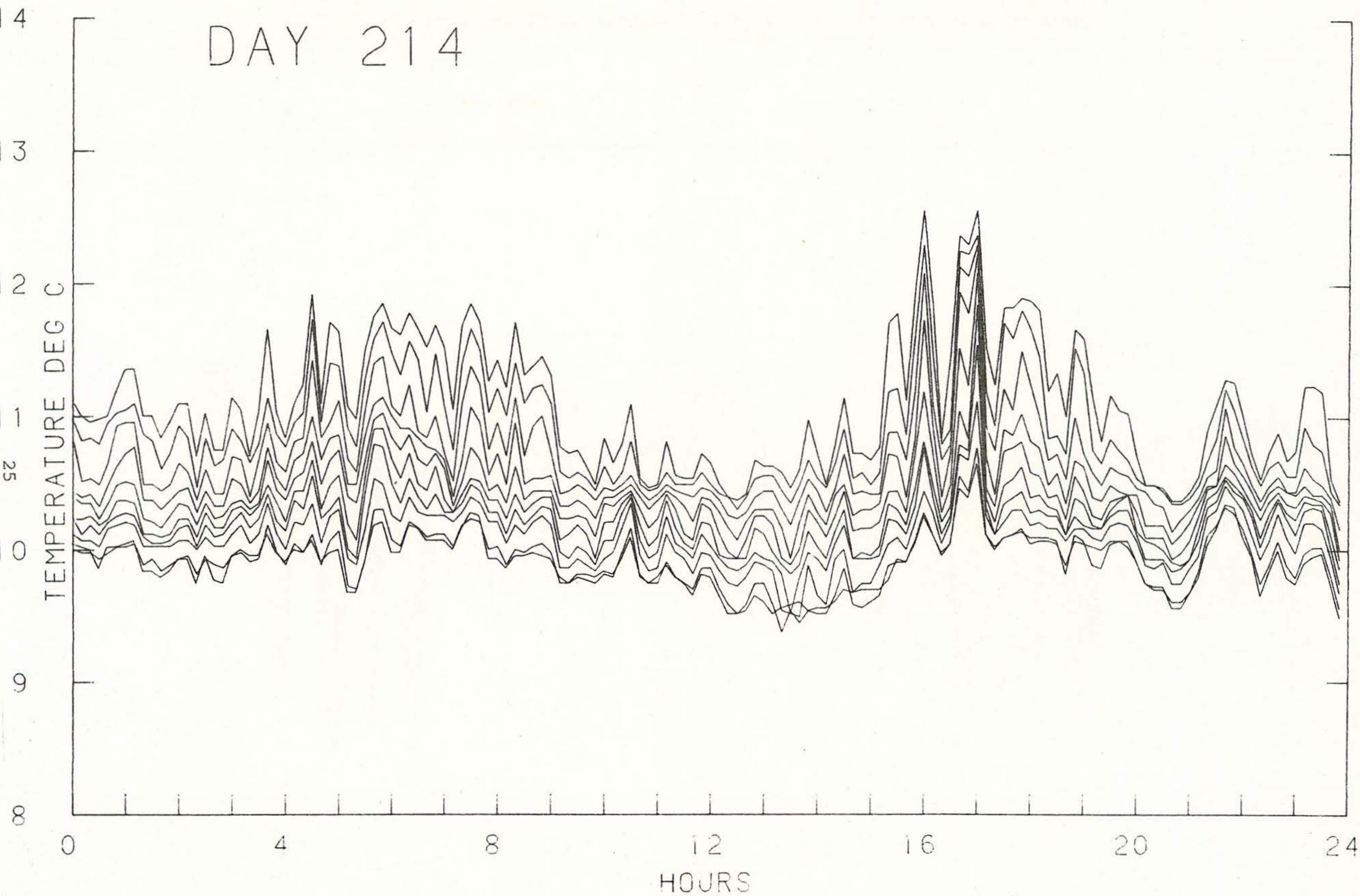

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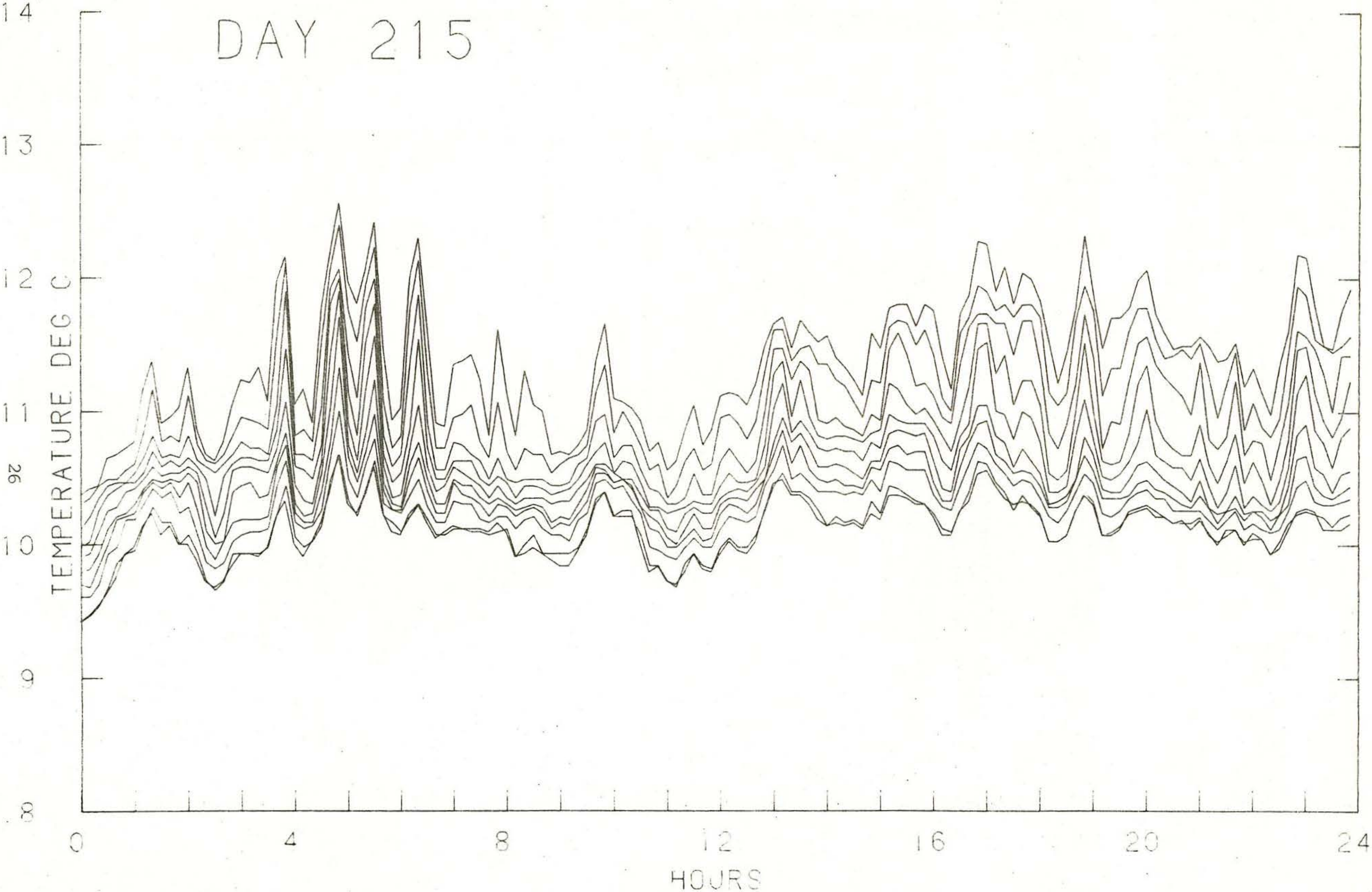

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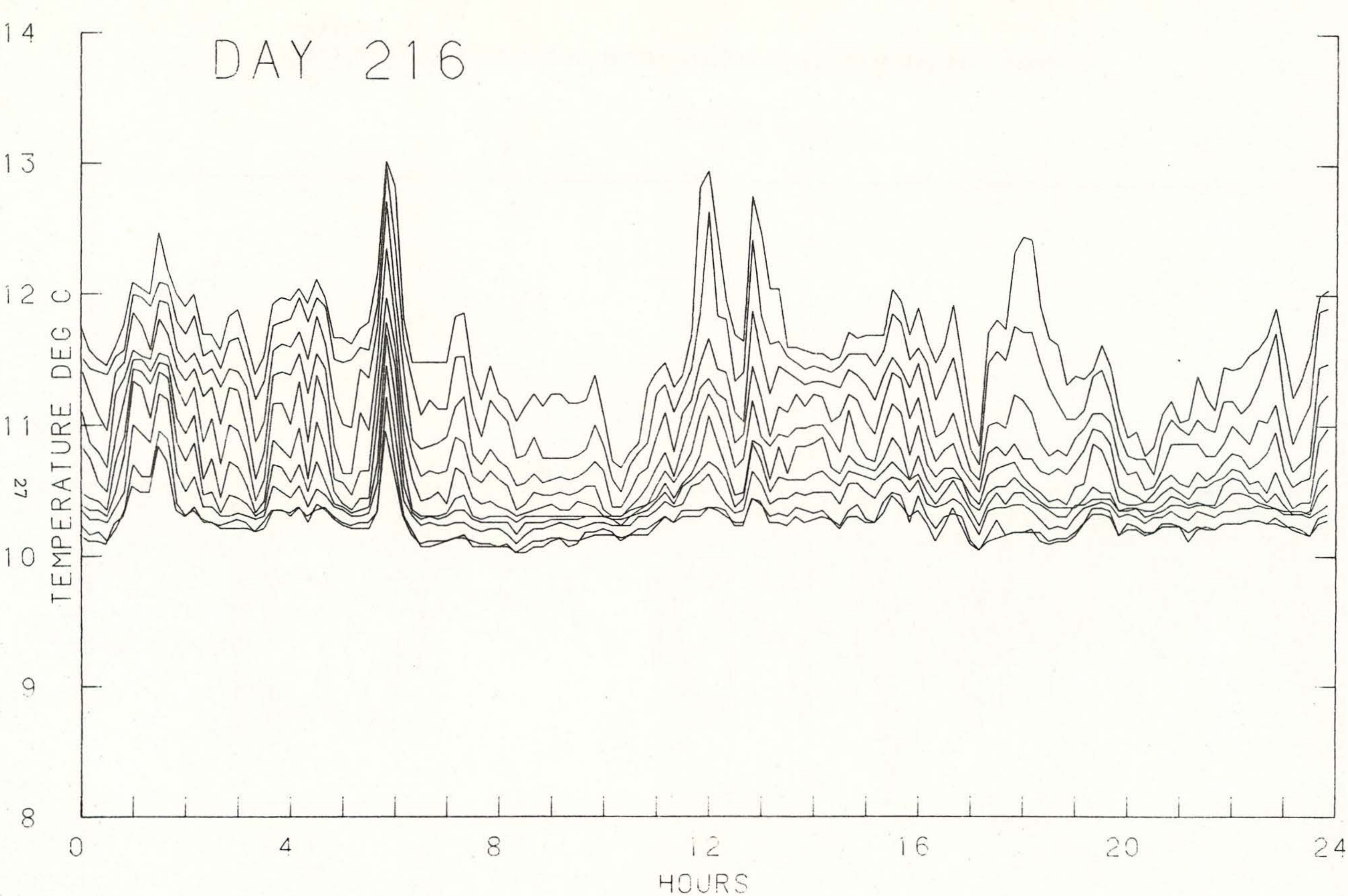

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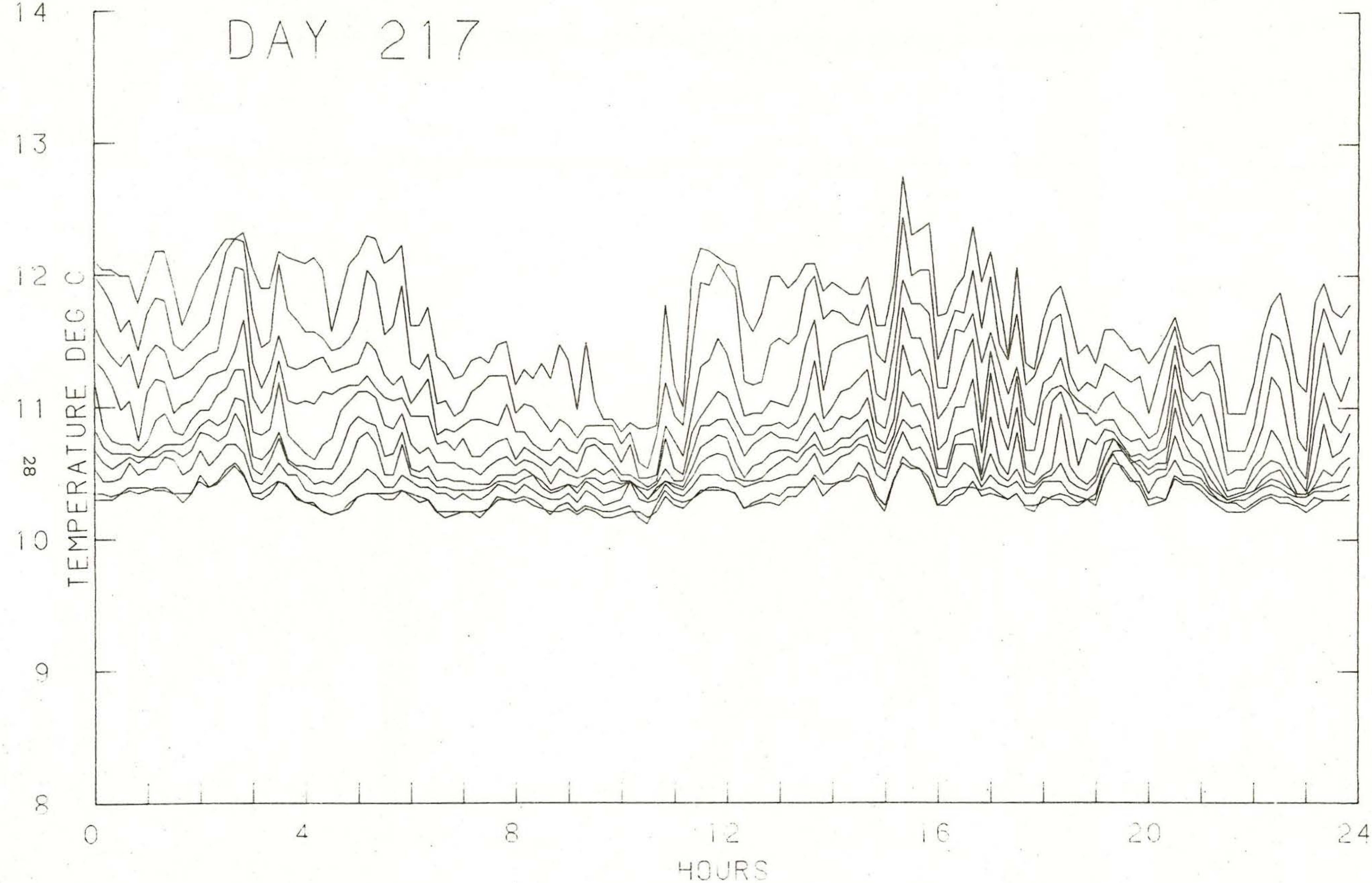

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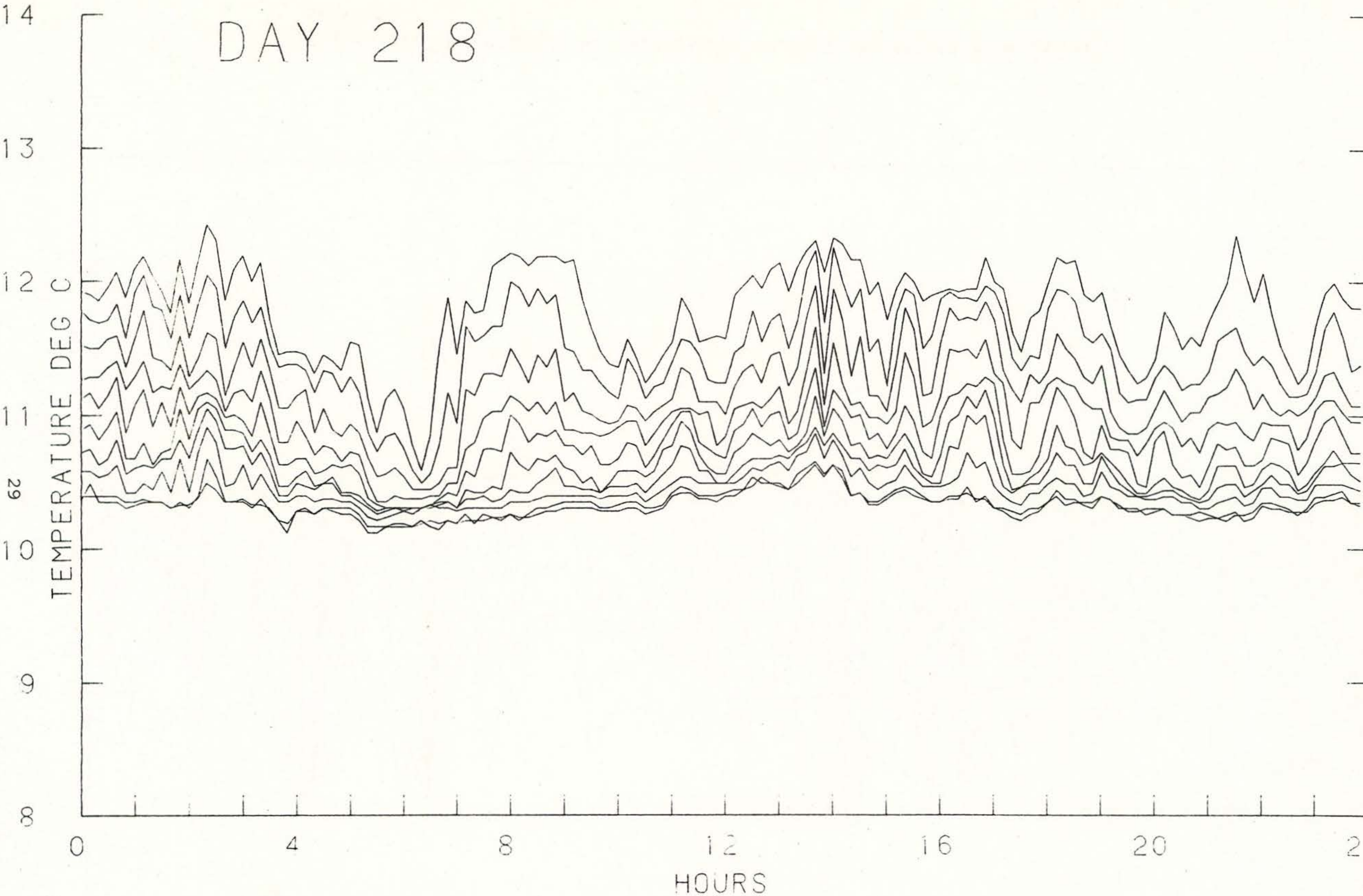

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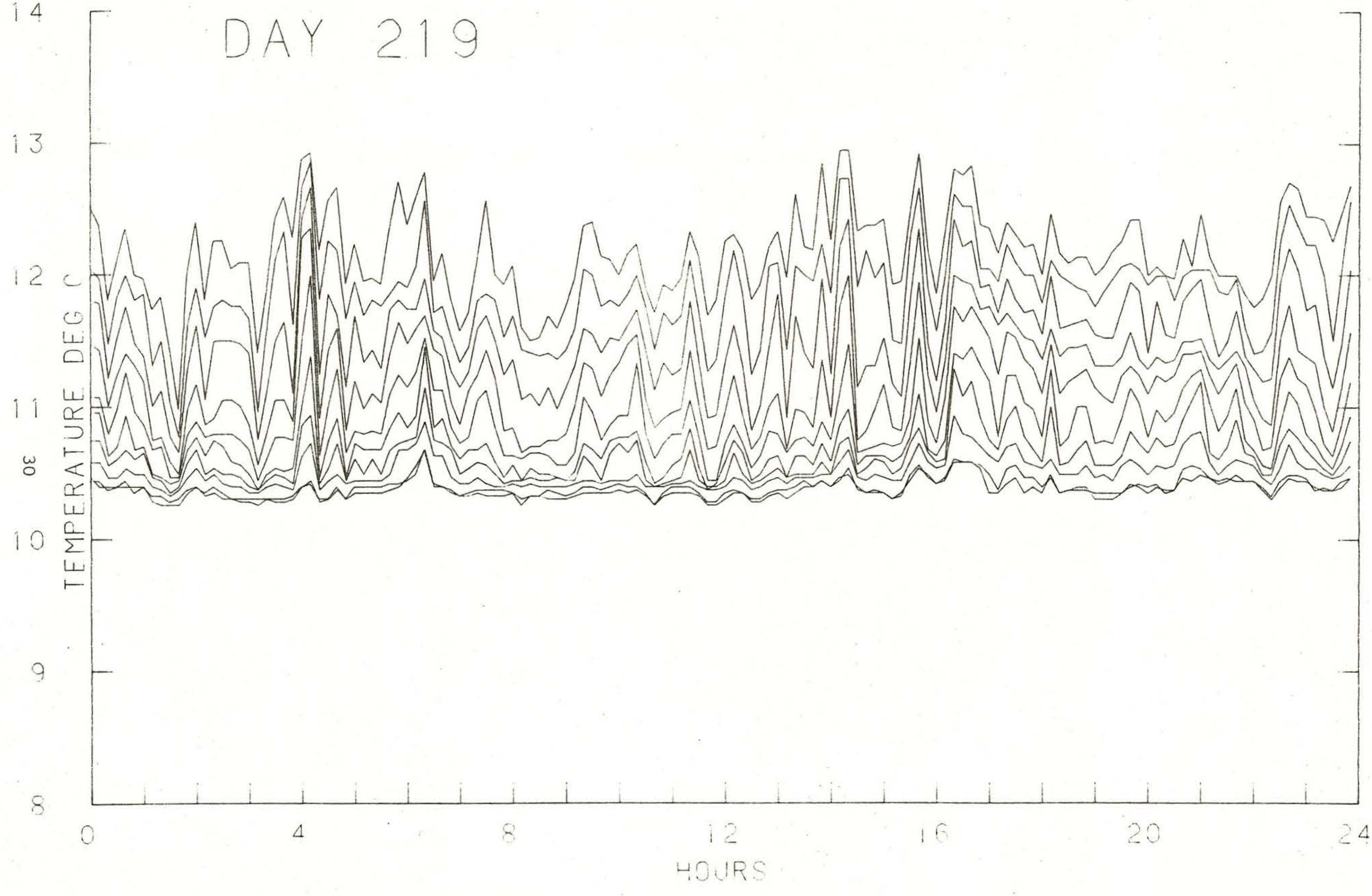

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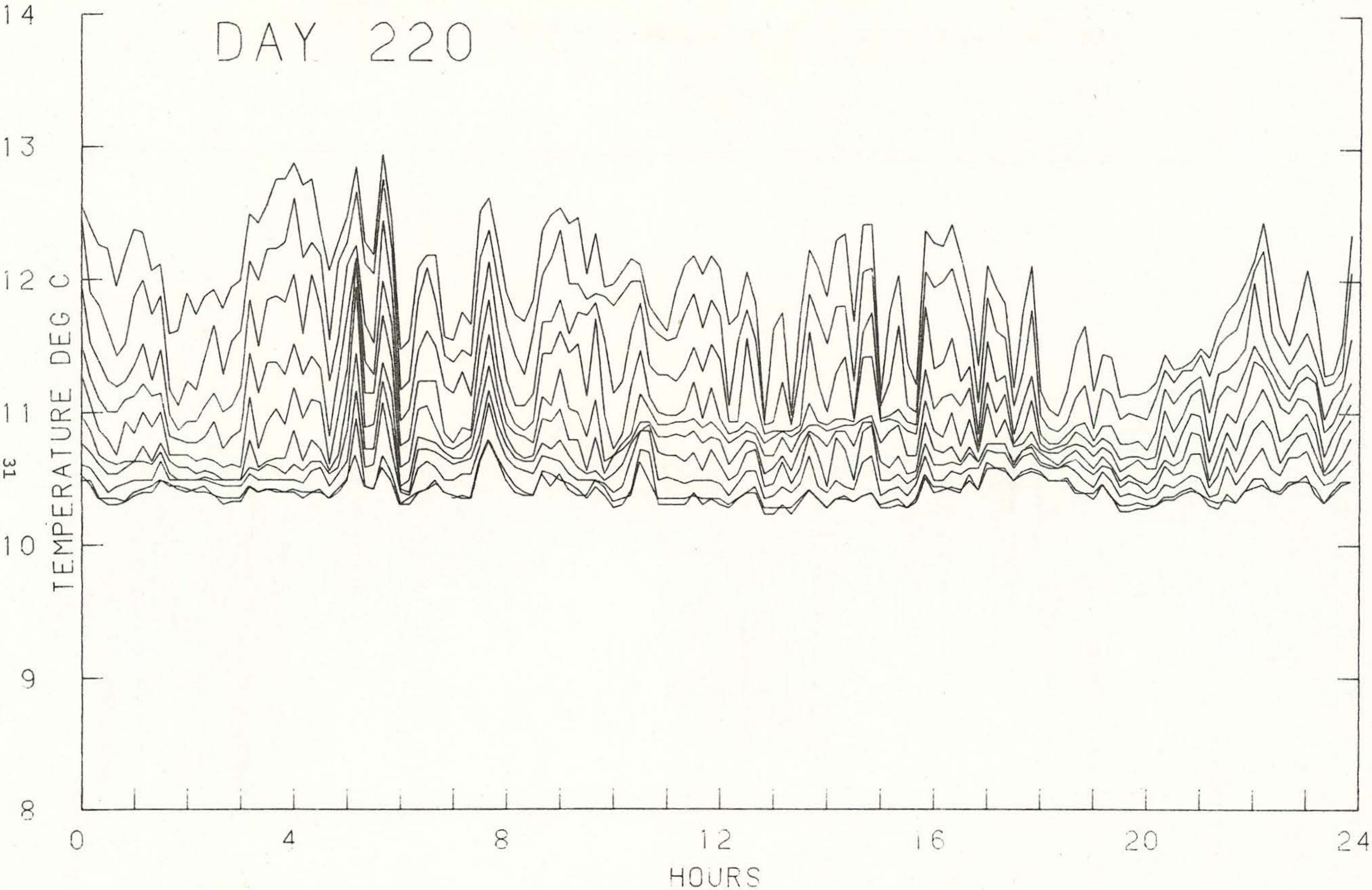
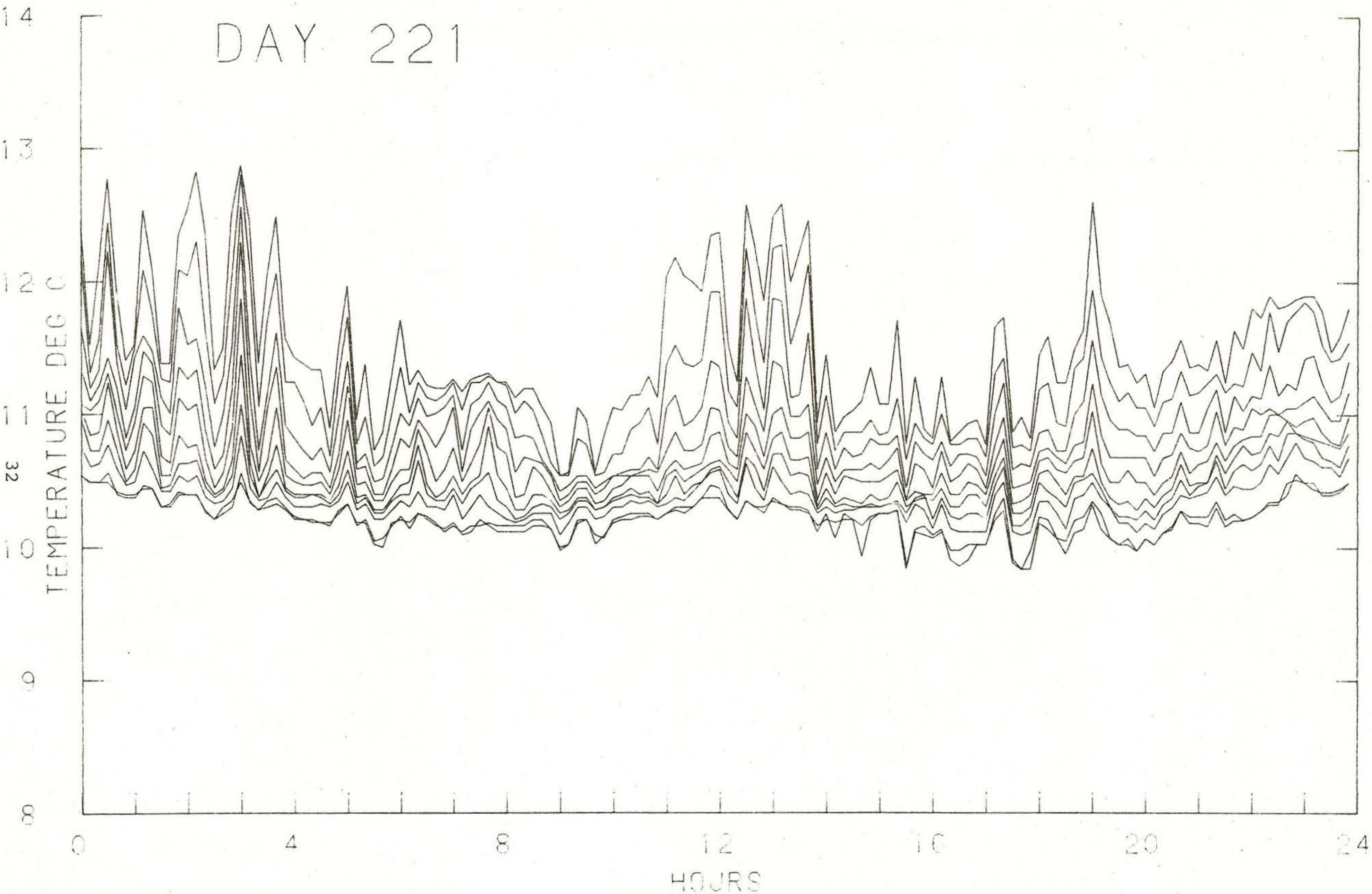


Figure 15. Temperature at 31,34,37,40,43,46,49,52,55 and 58 m (nominal depths).



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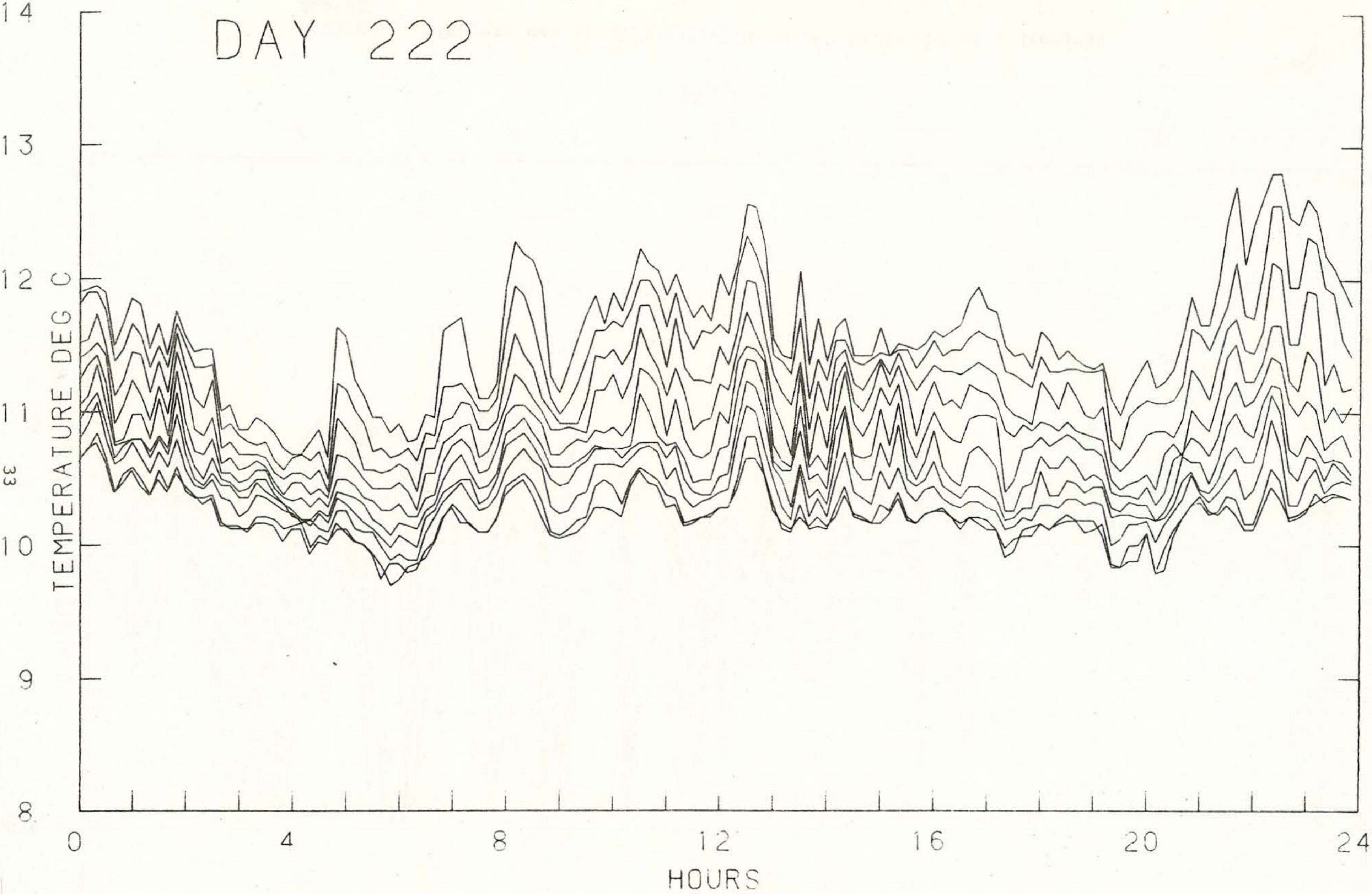

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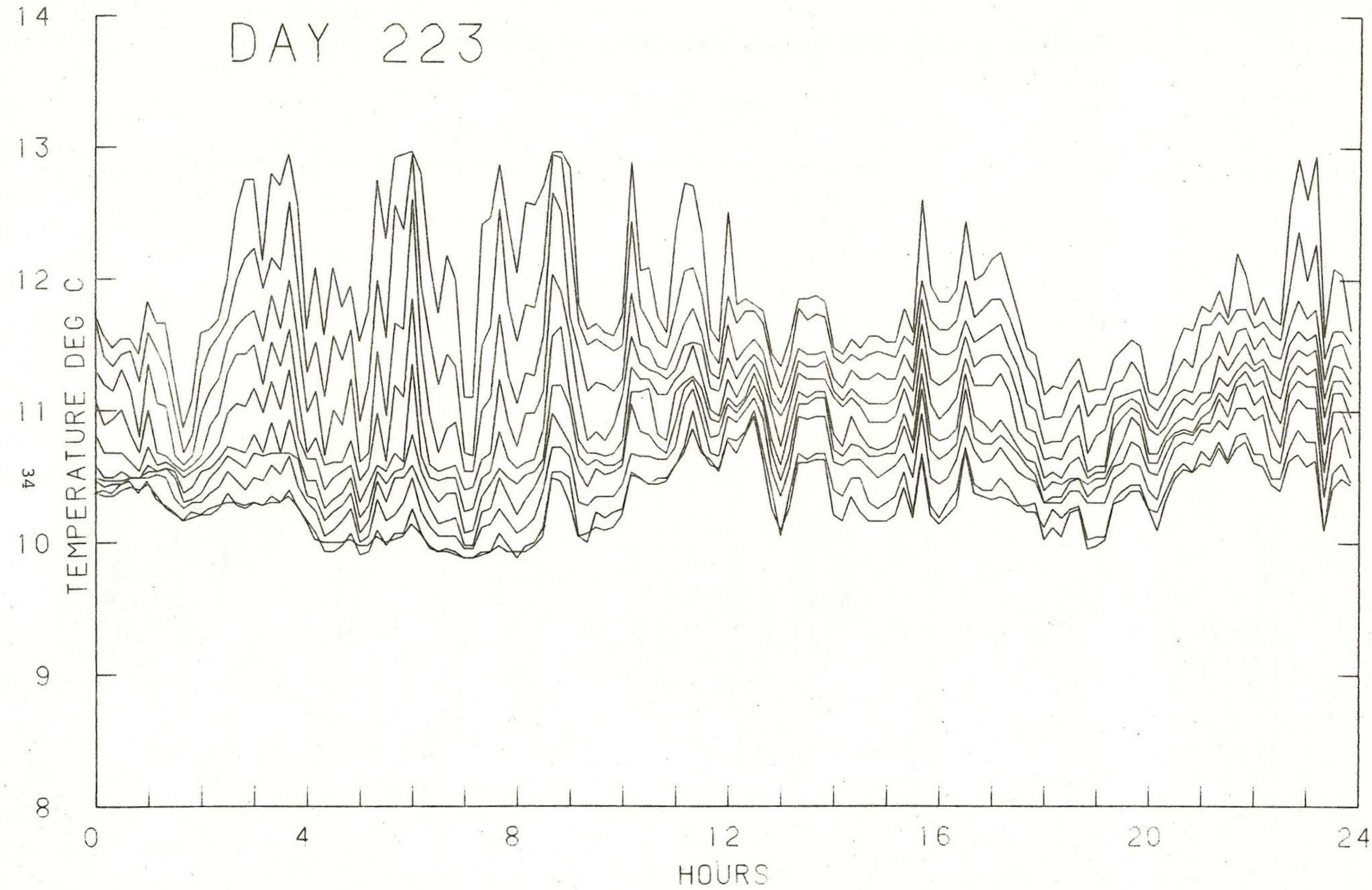

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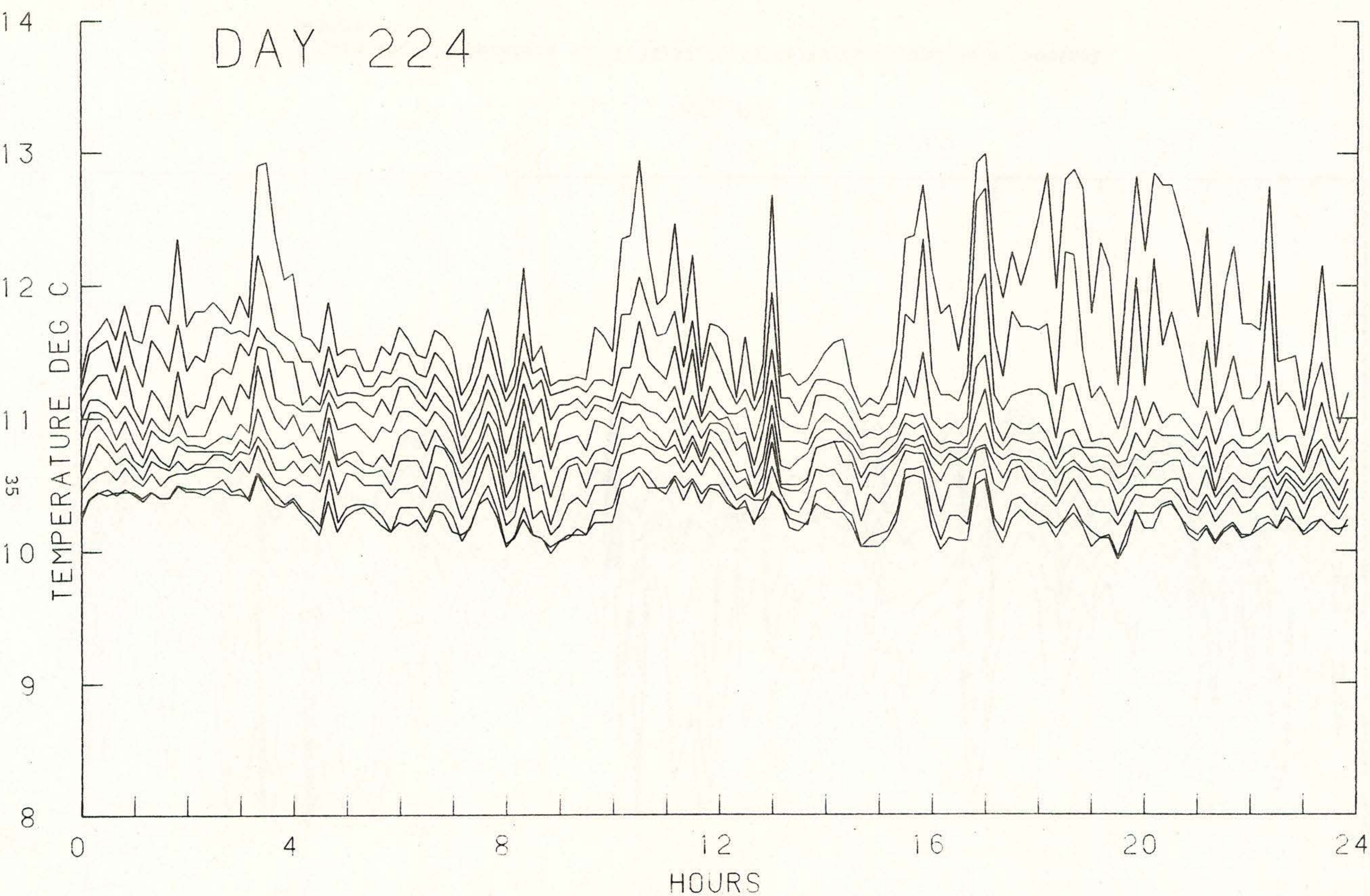

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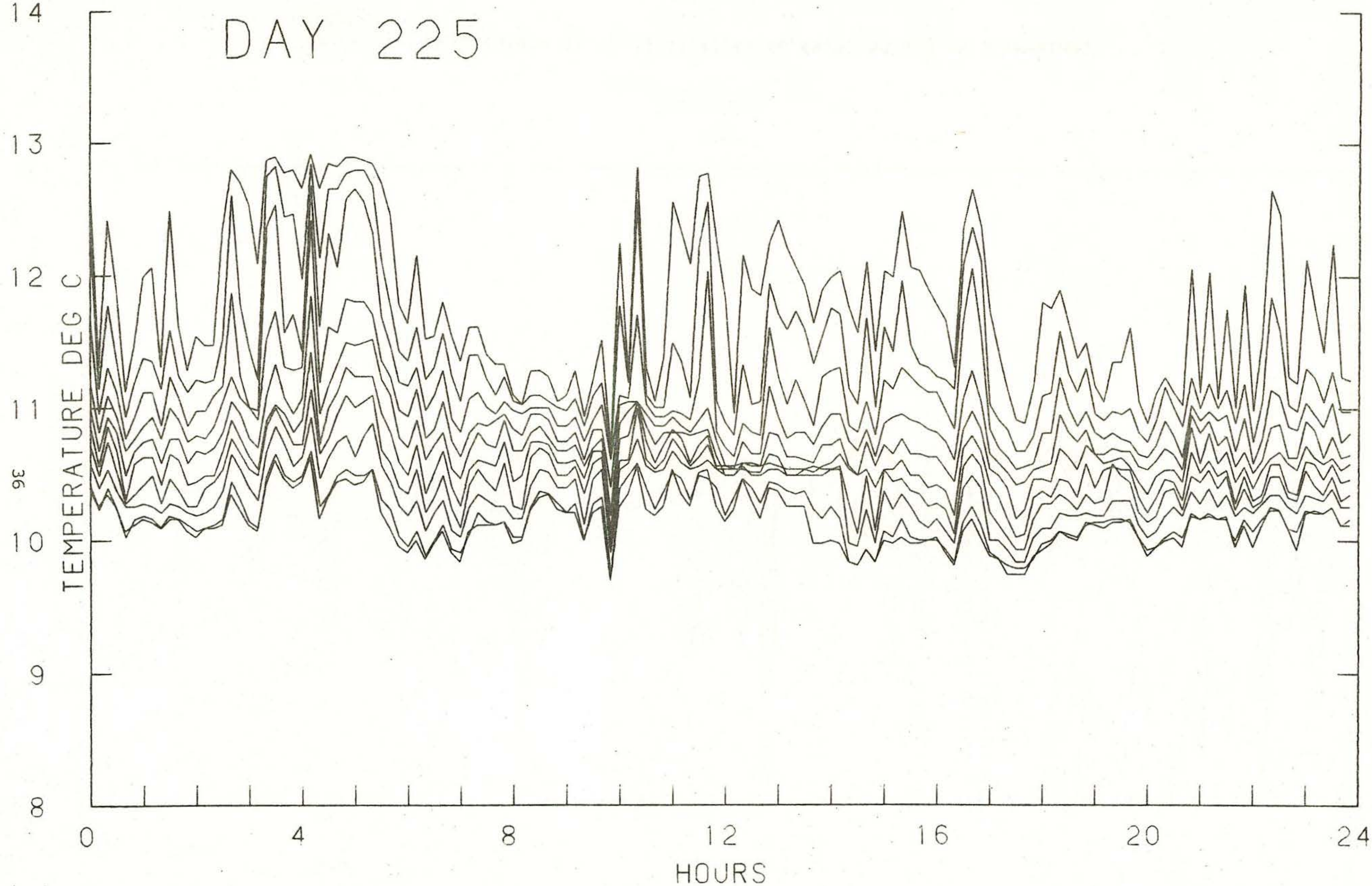

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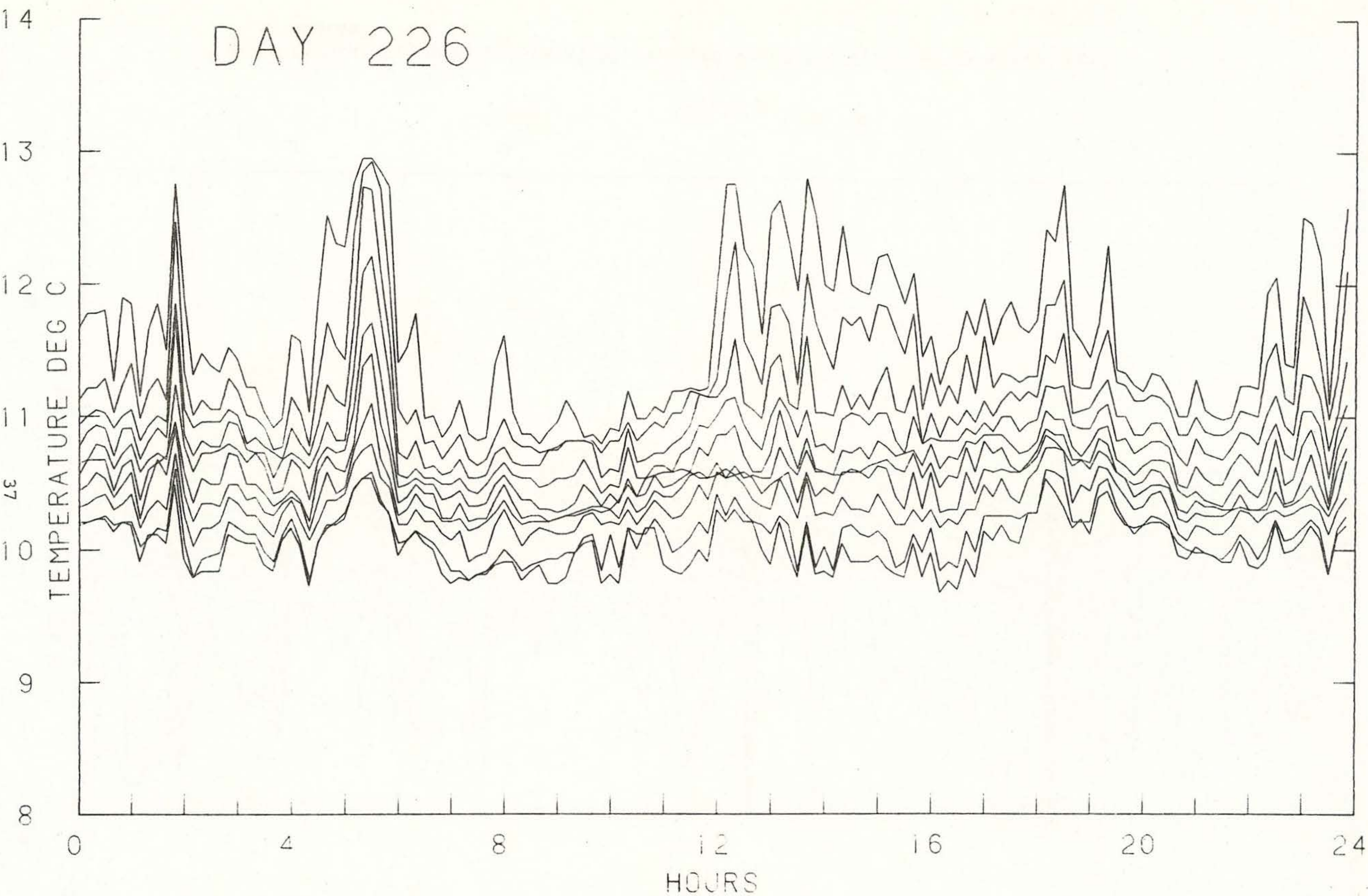

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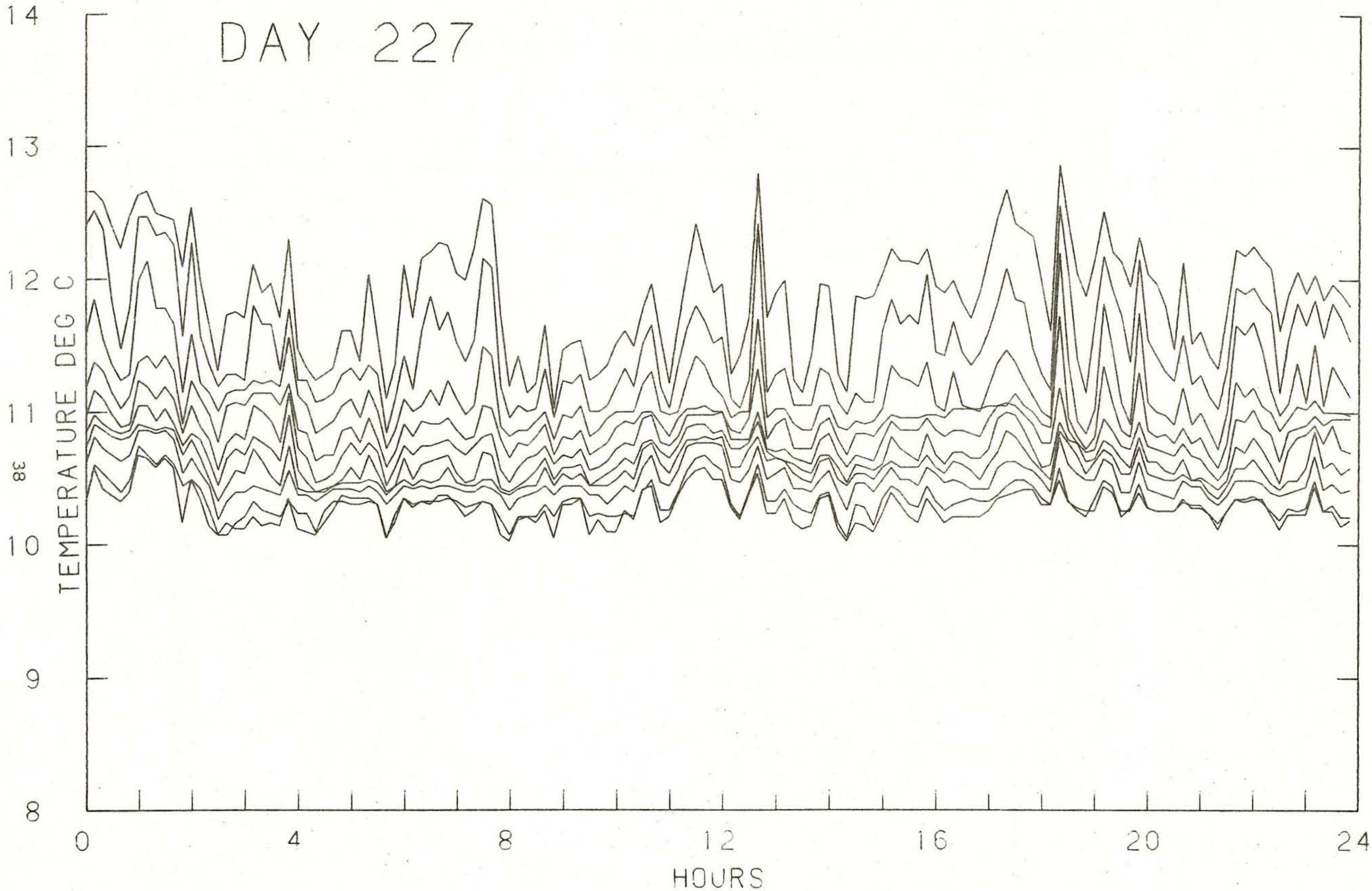

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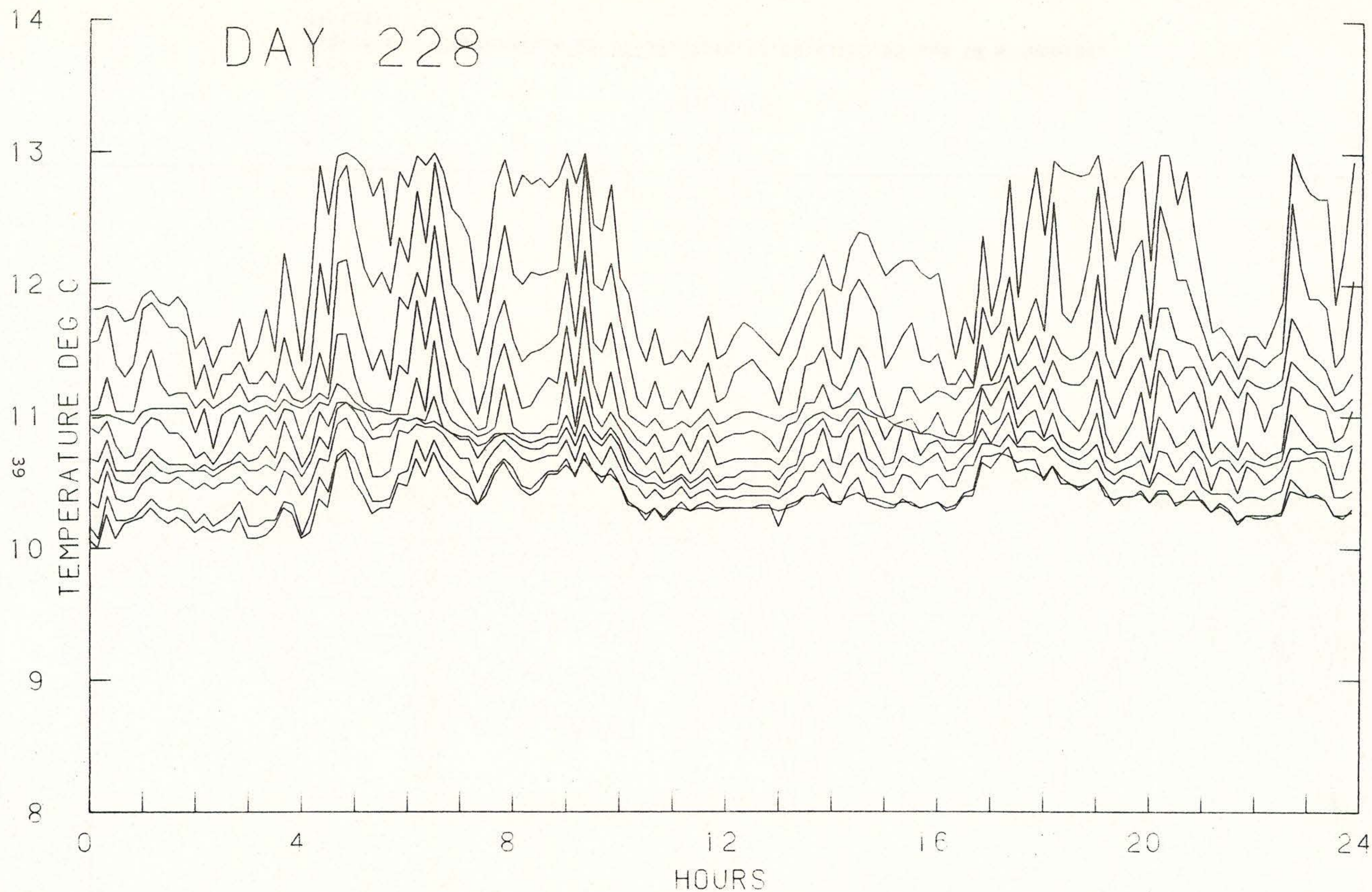

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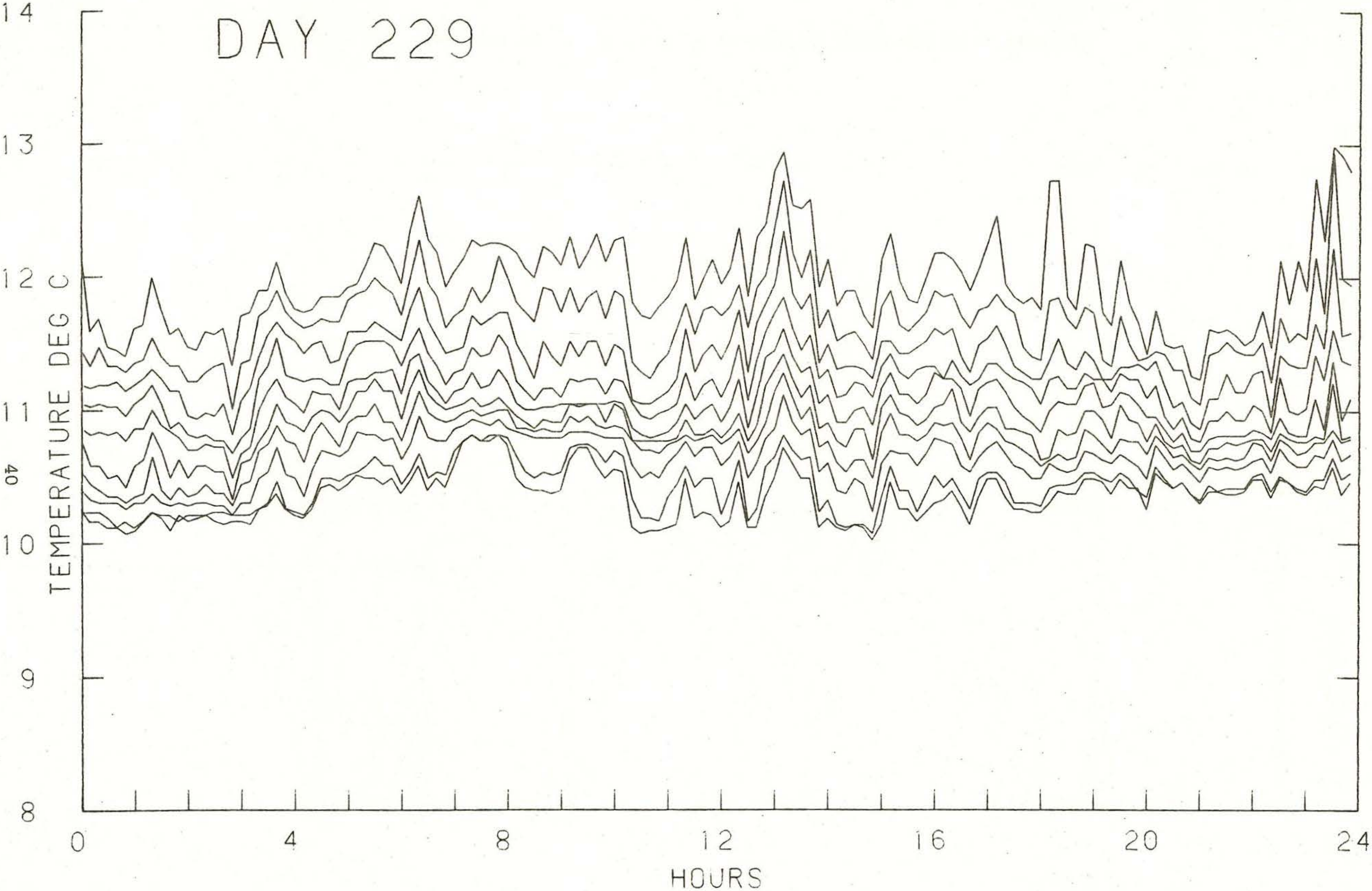

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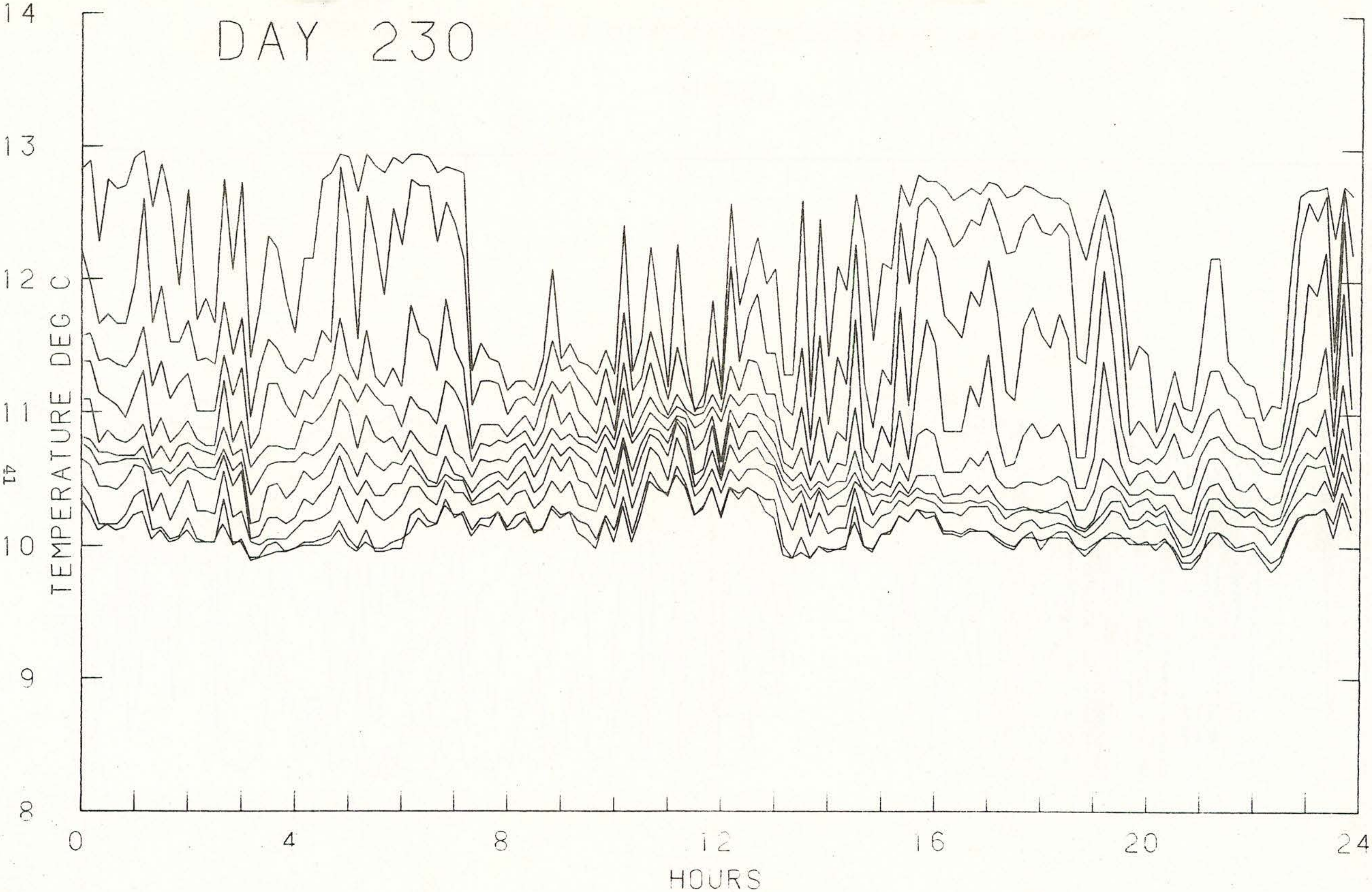

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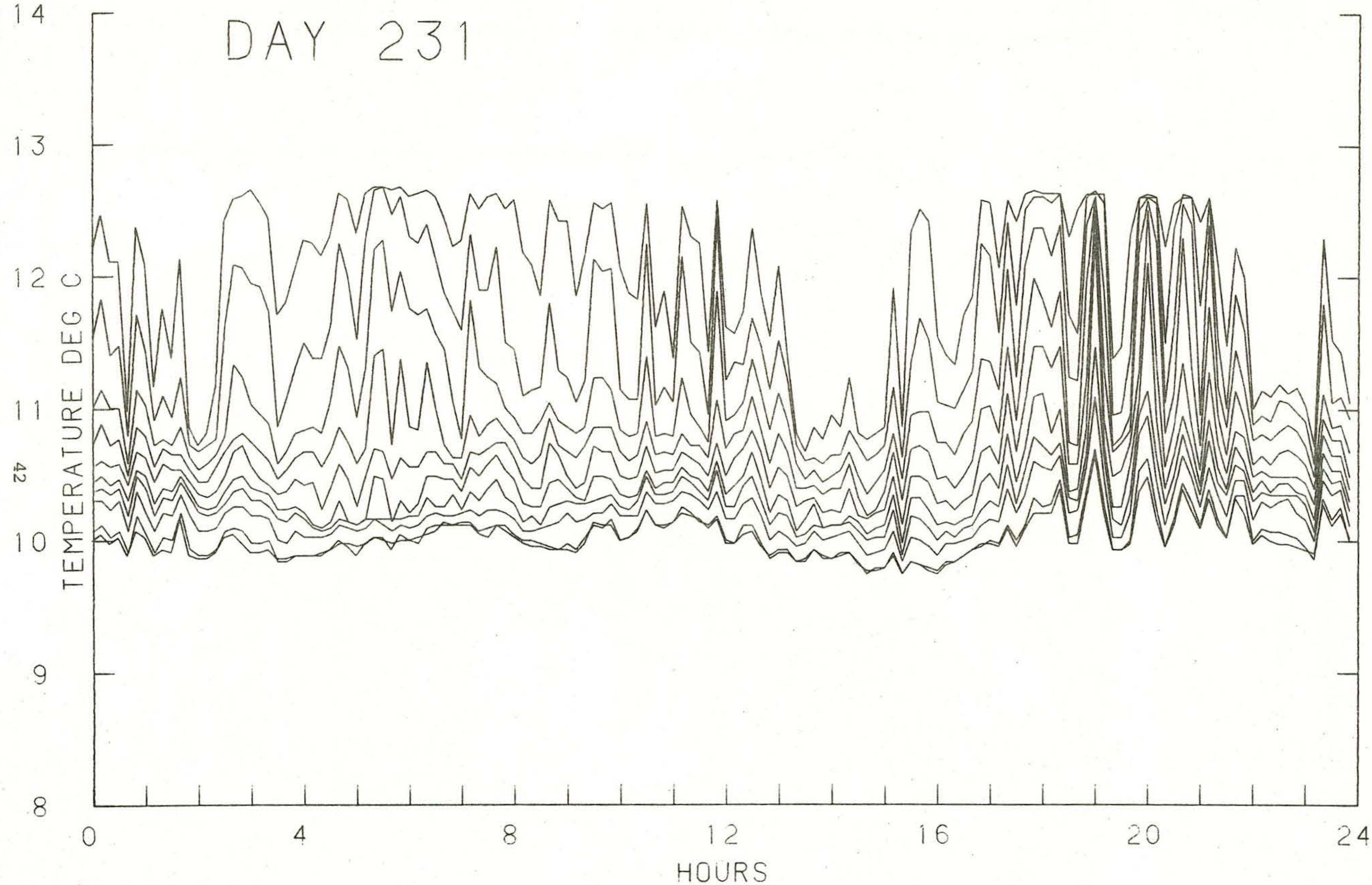

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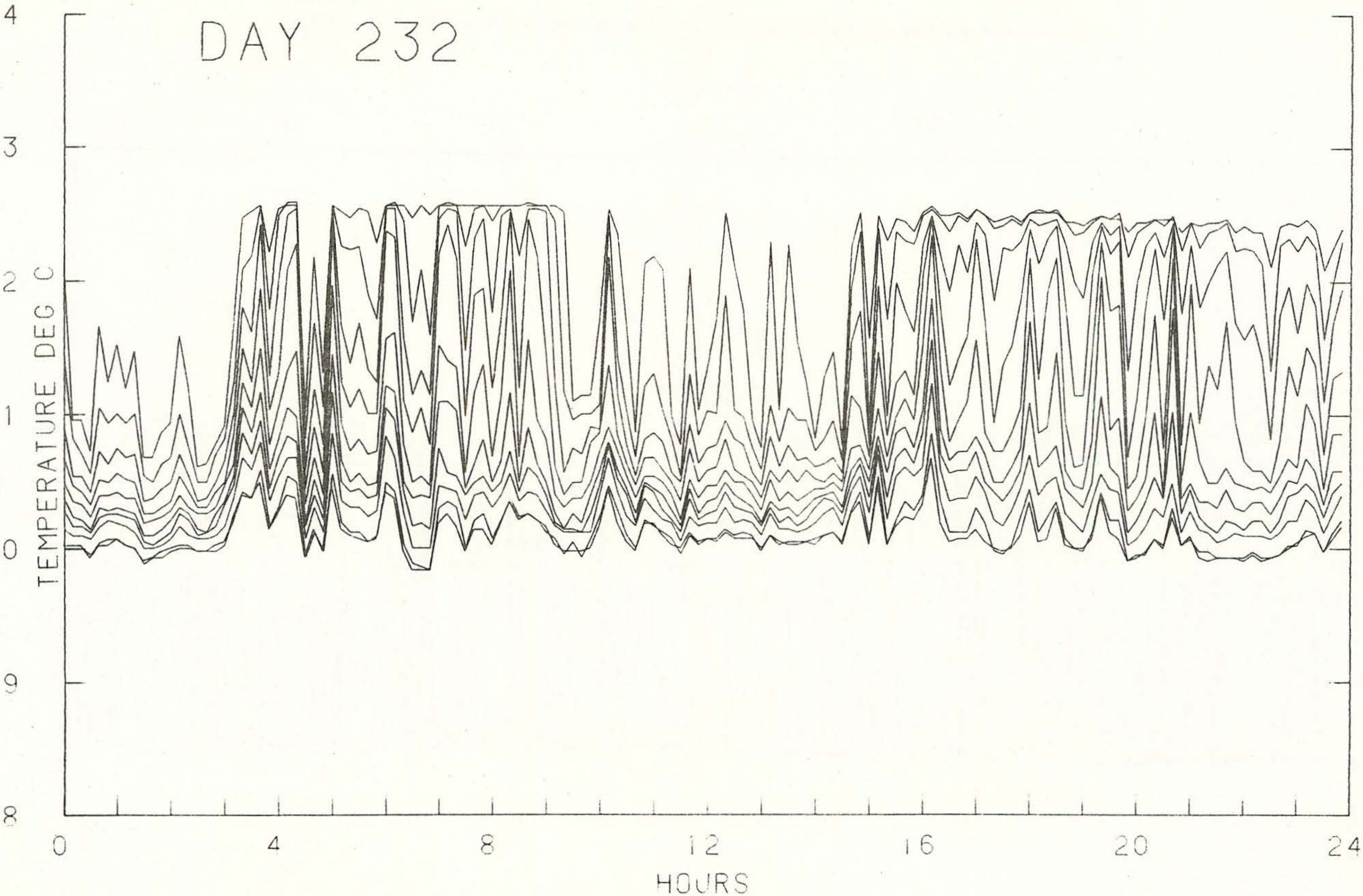

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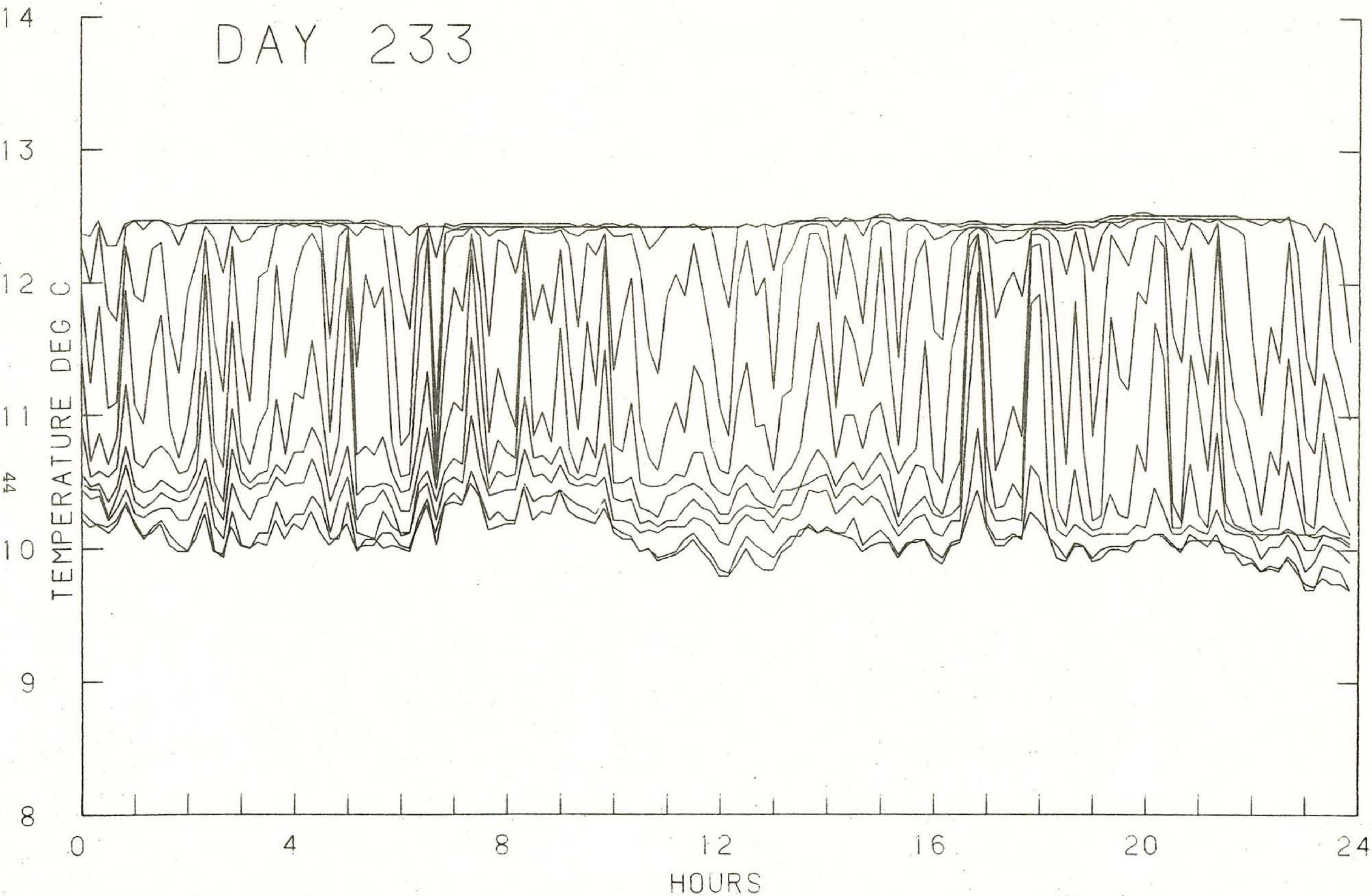

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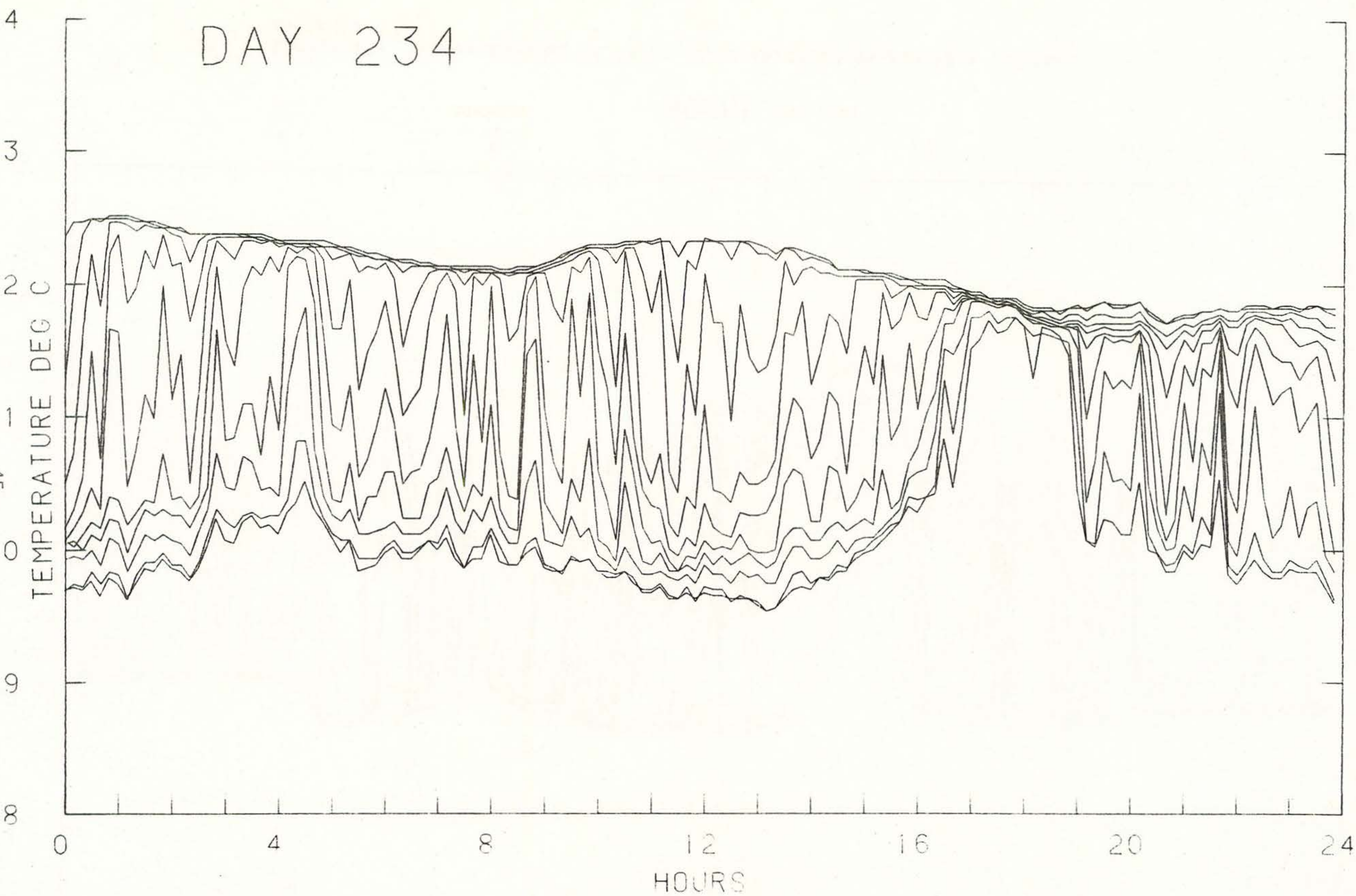

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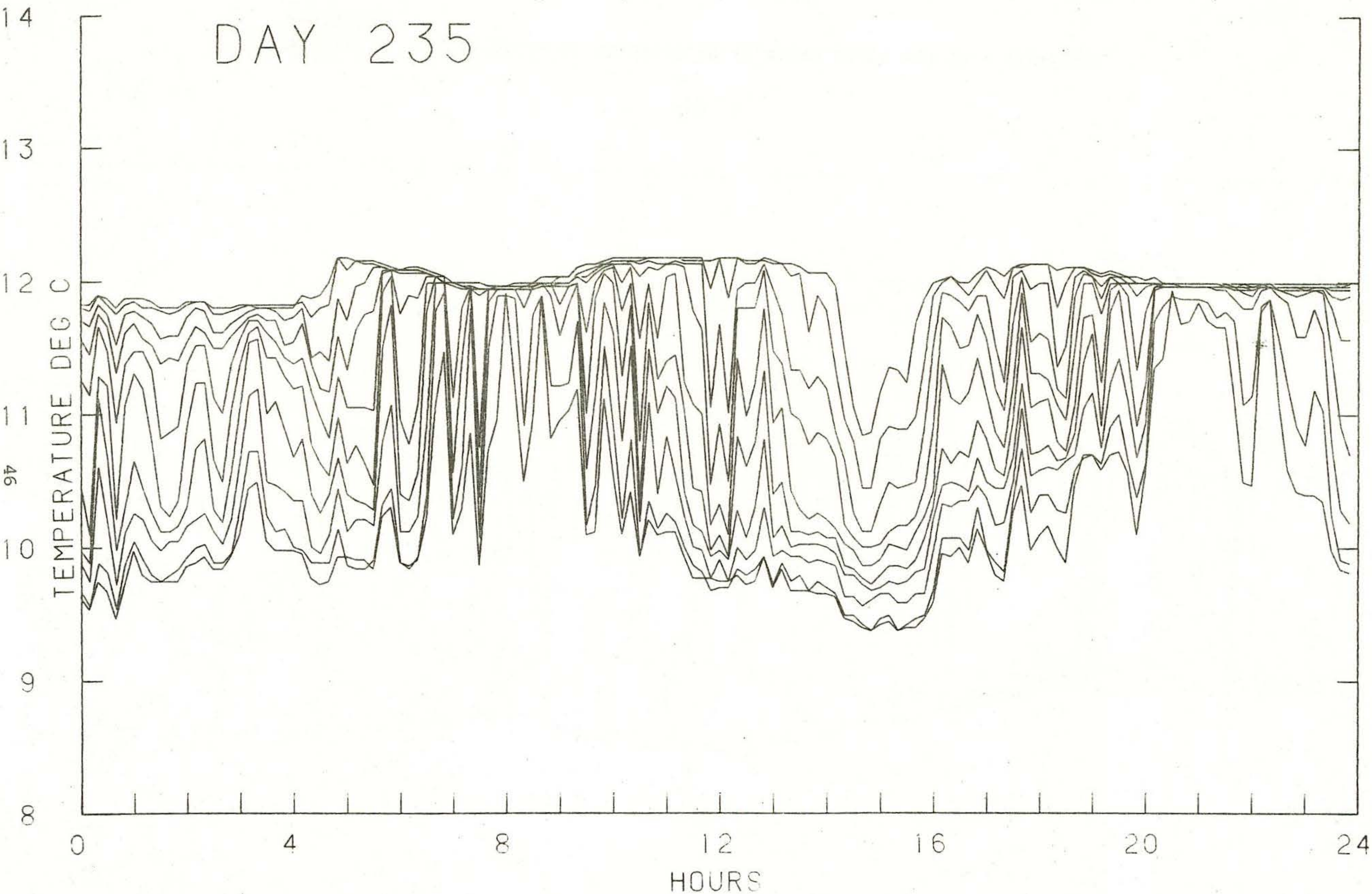

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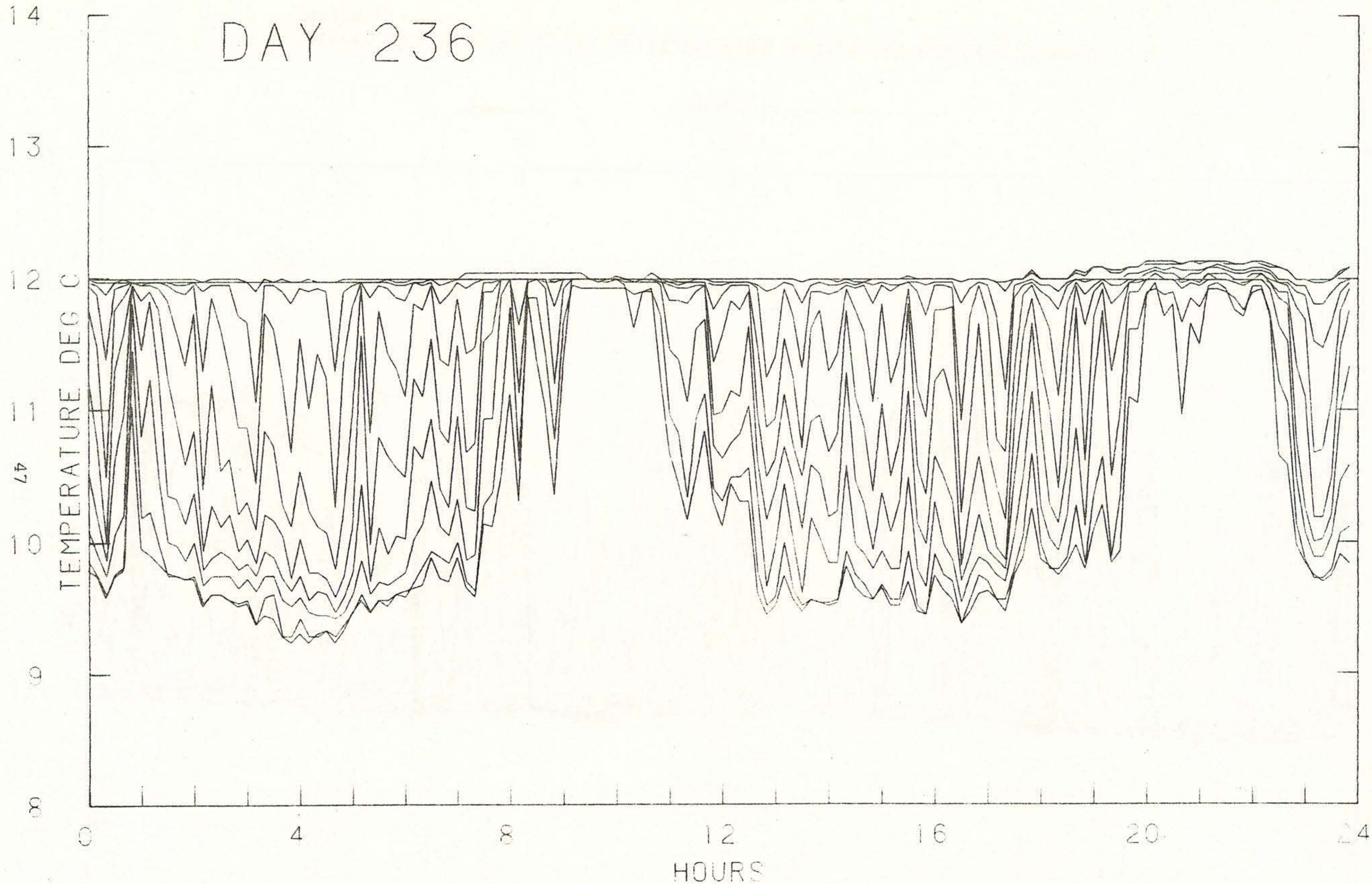

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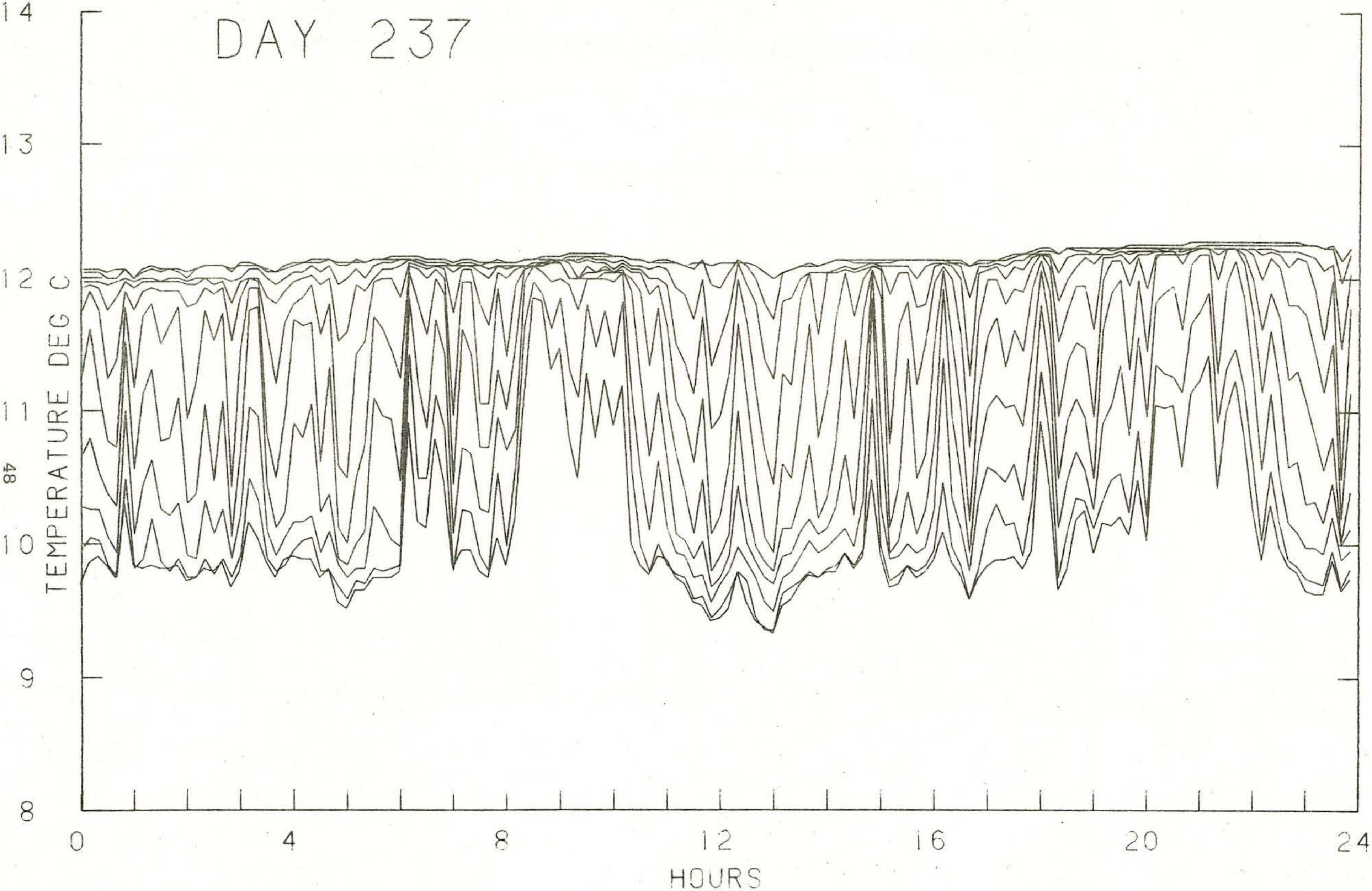

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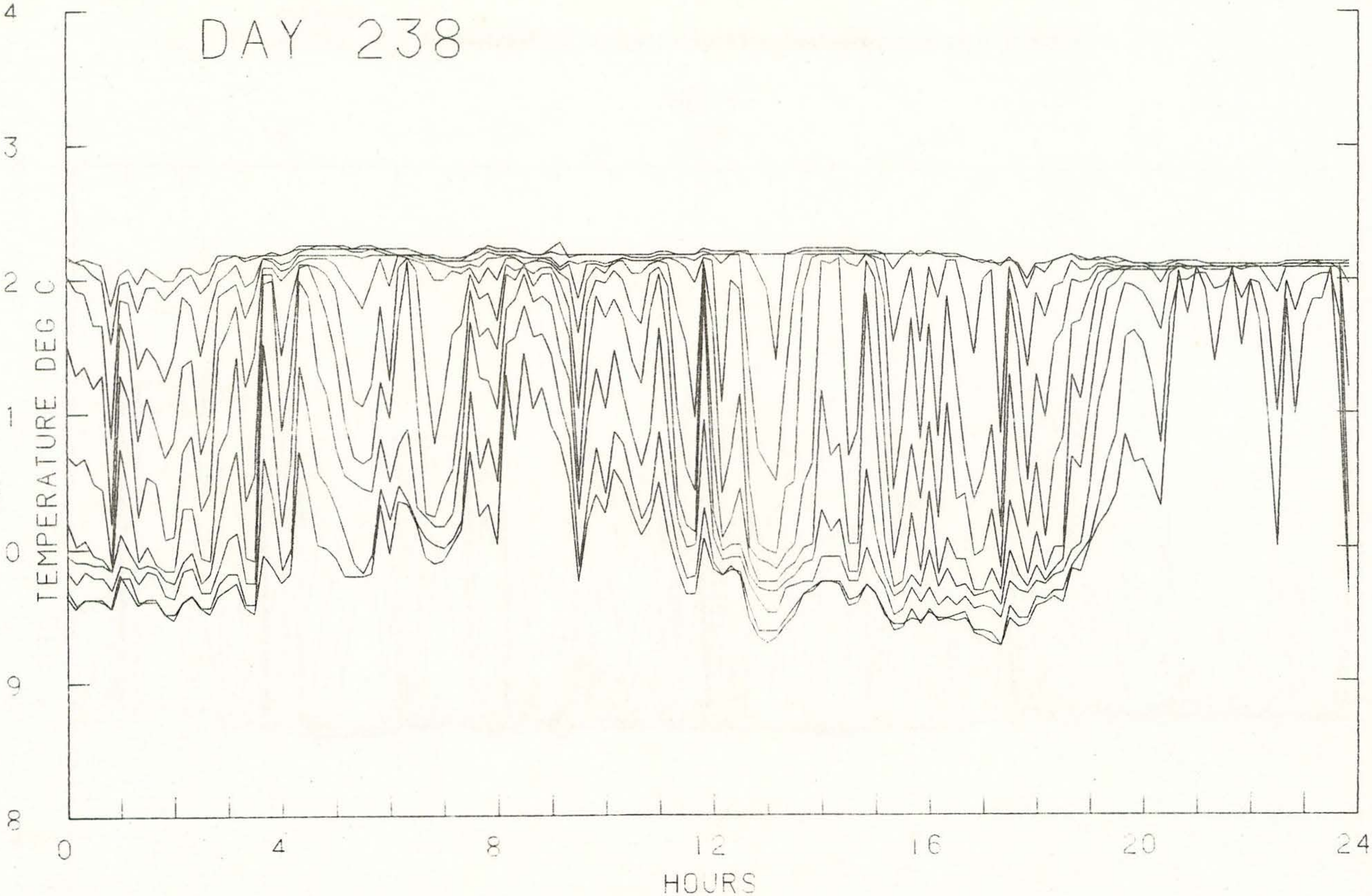

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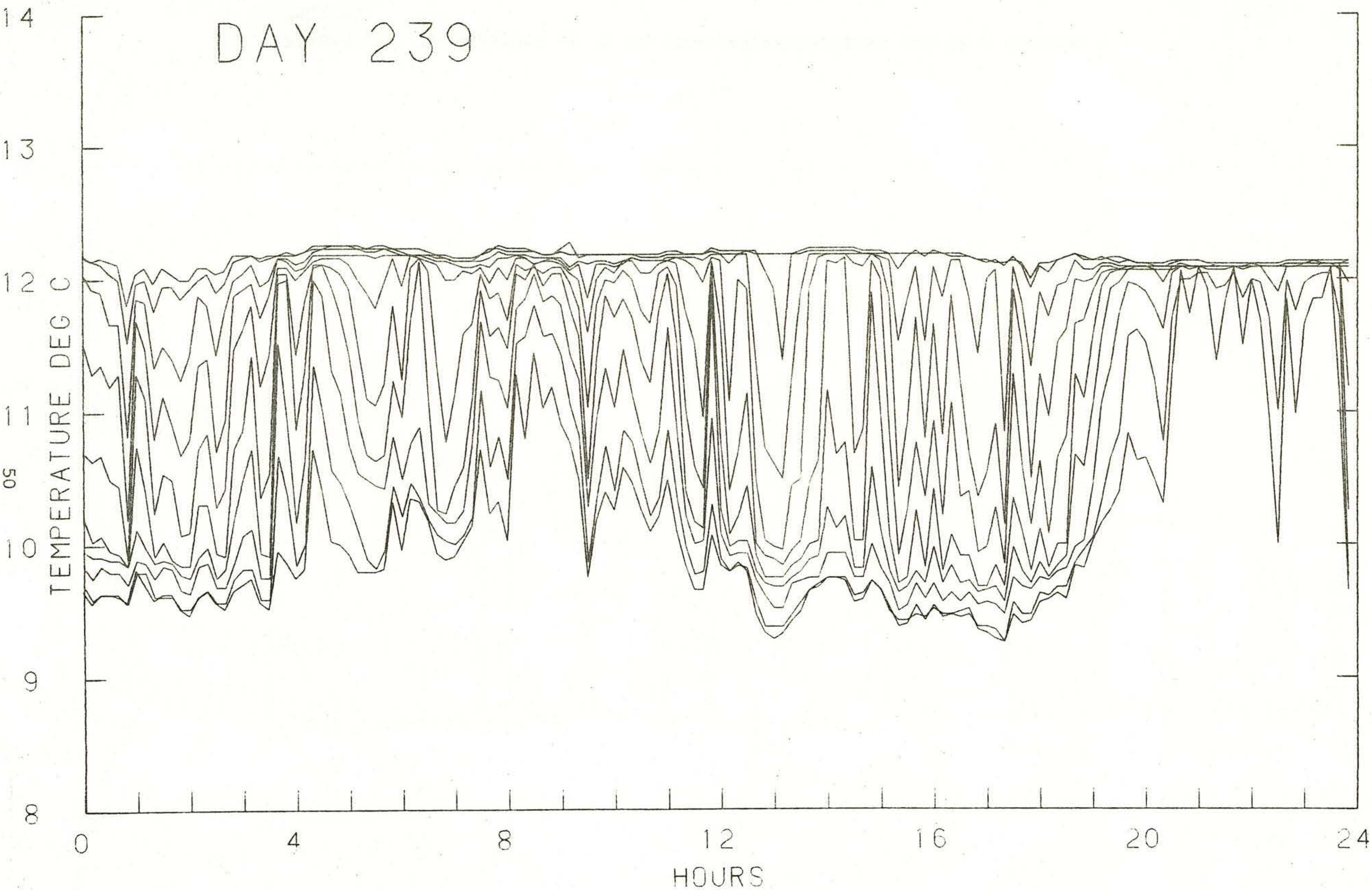

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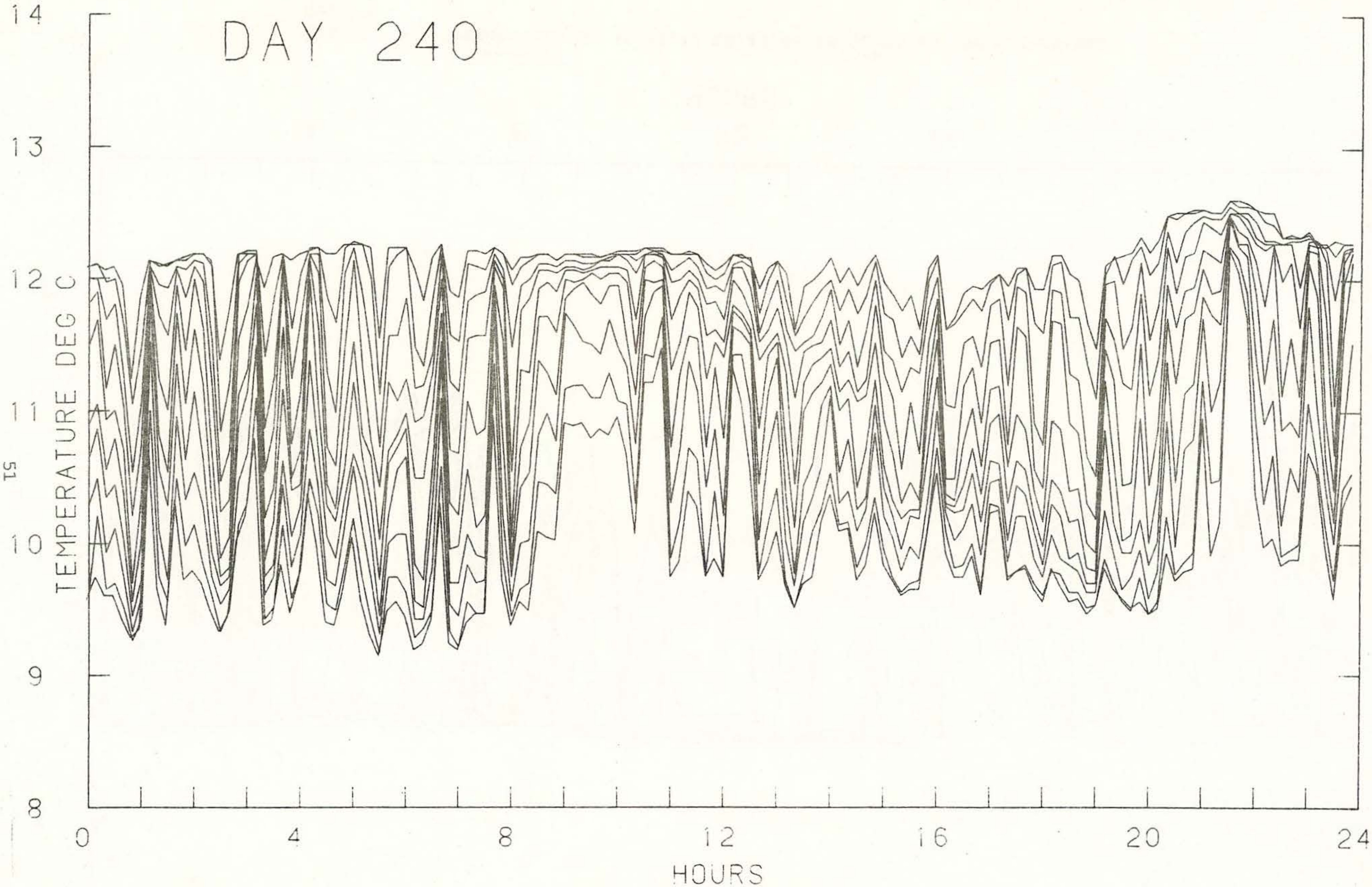

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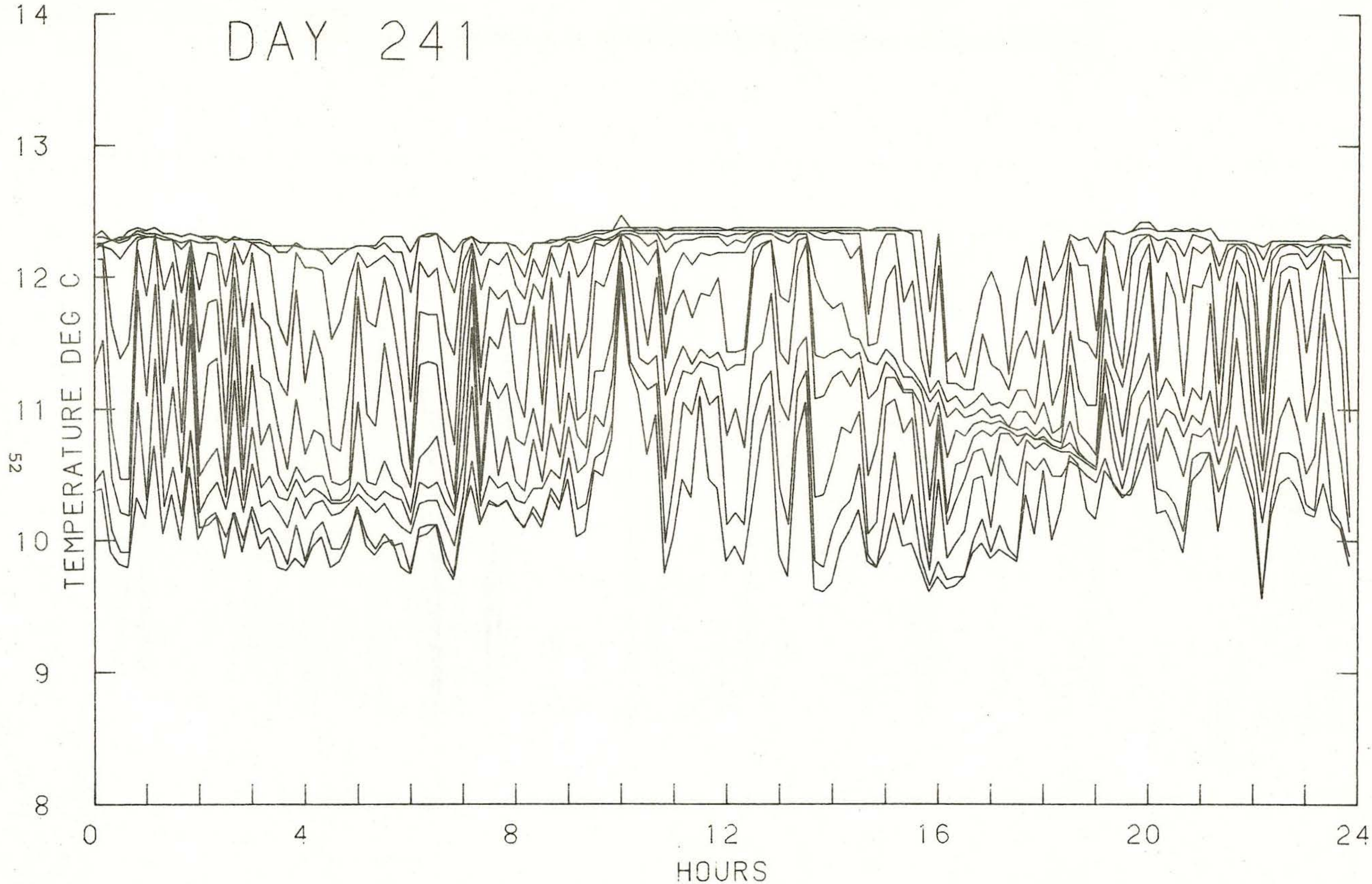

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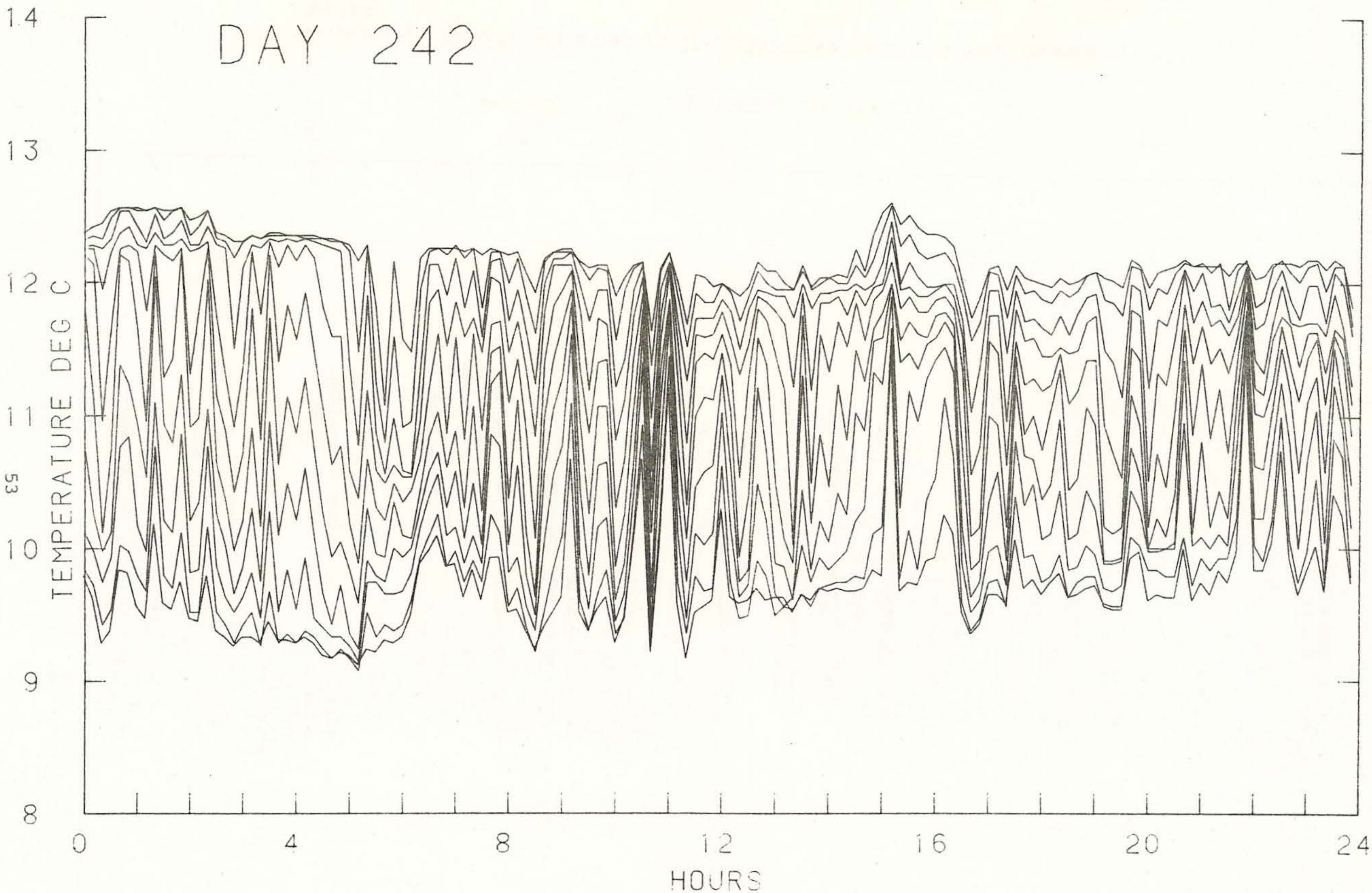

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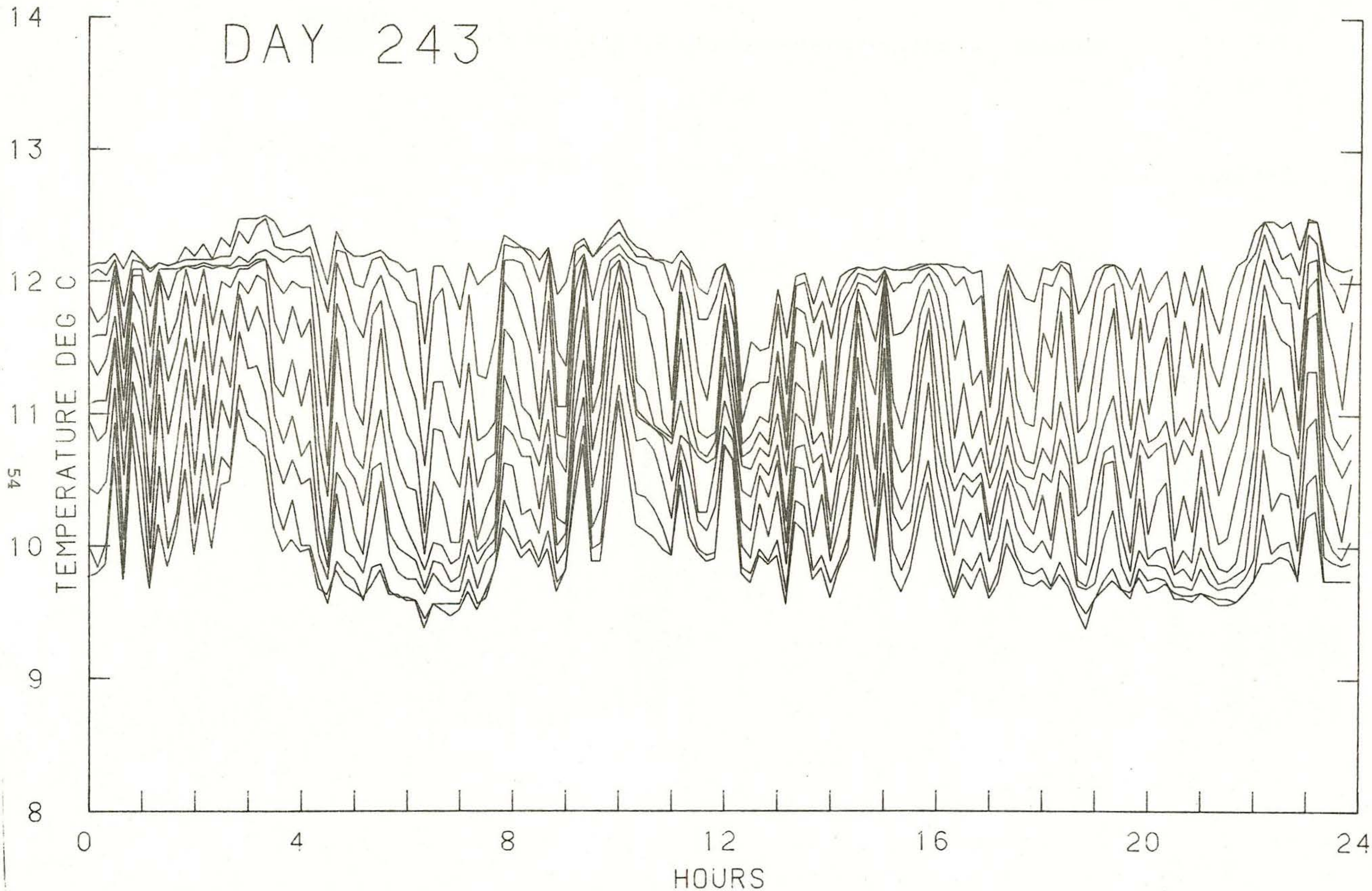

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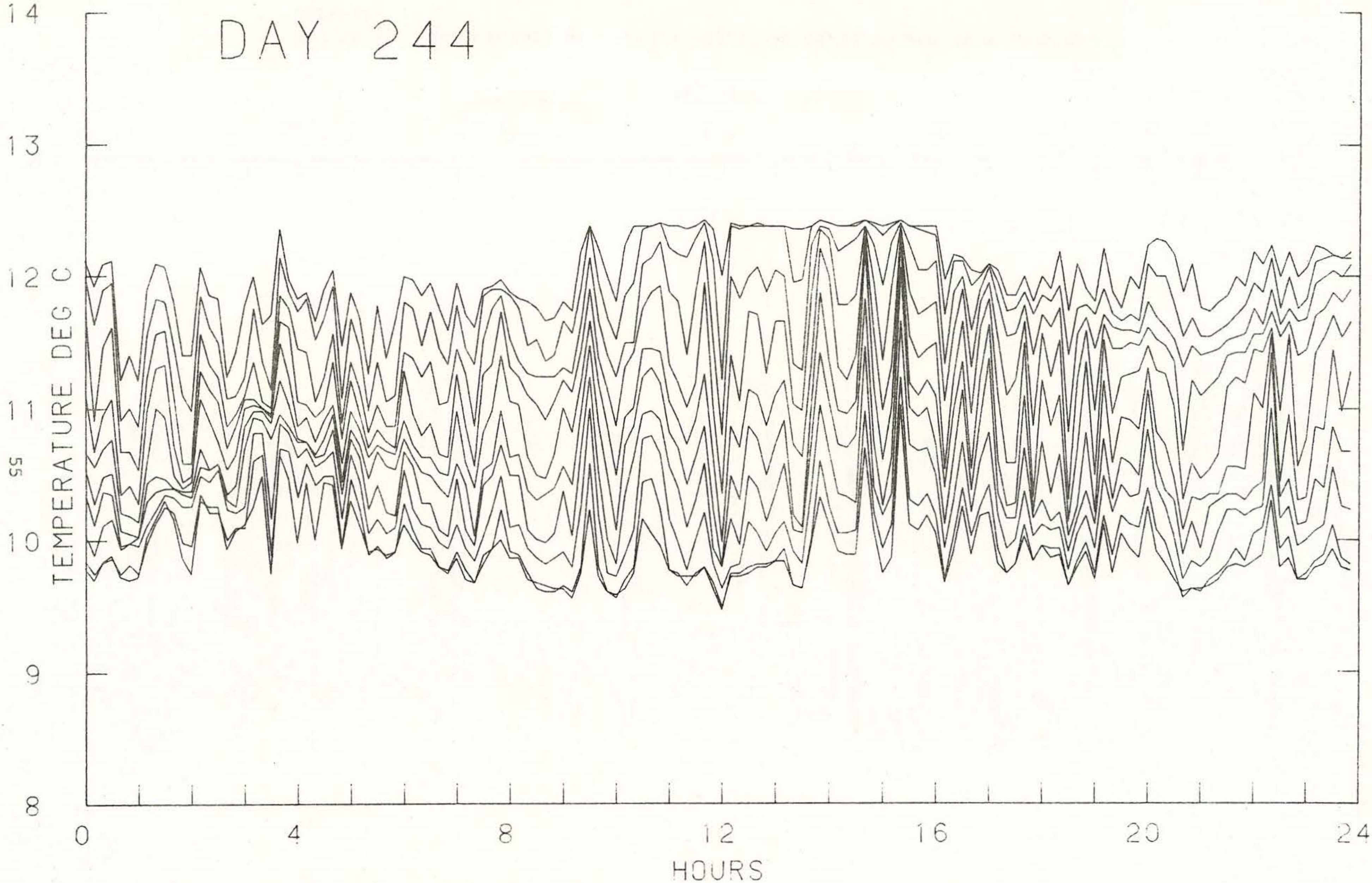

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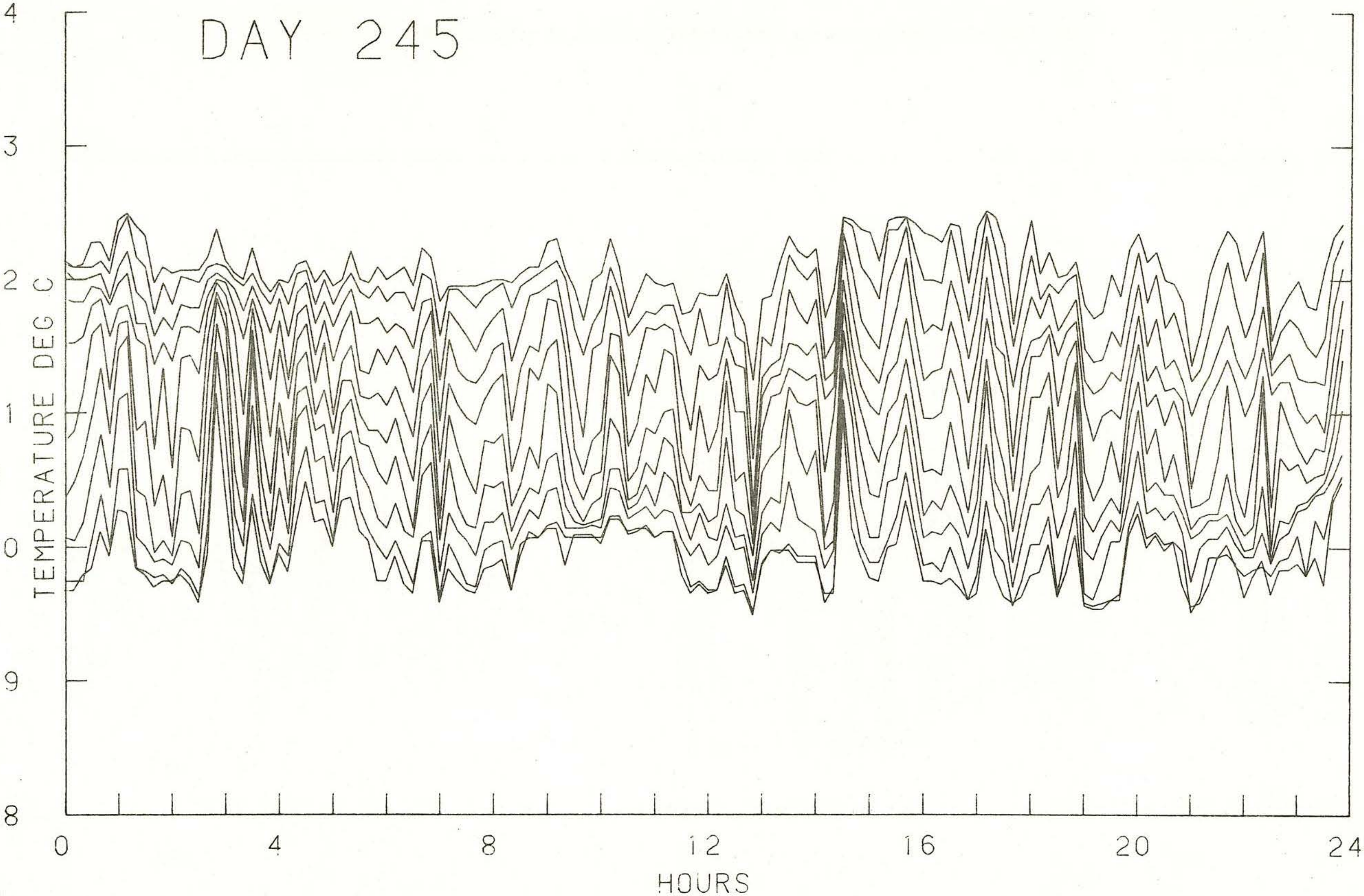

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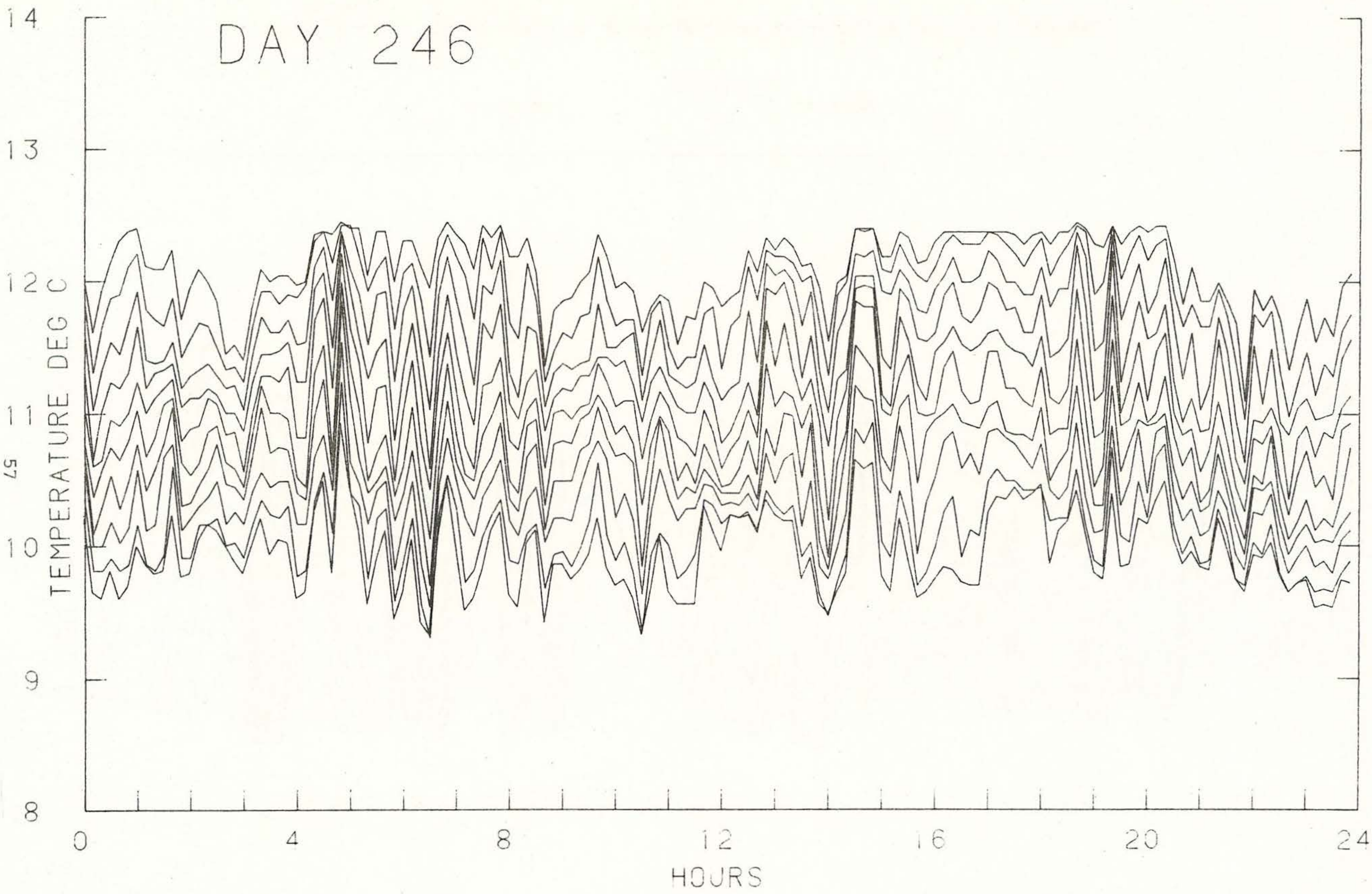

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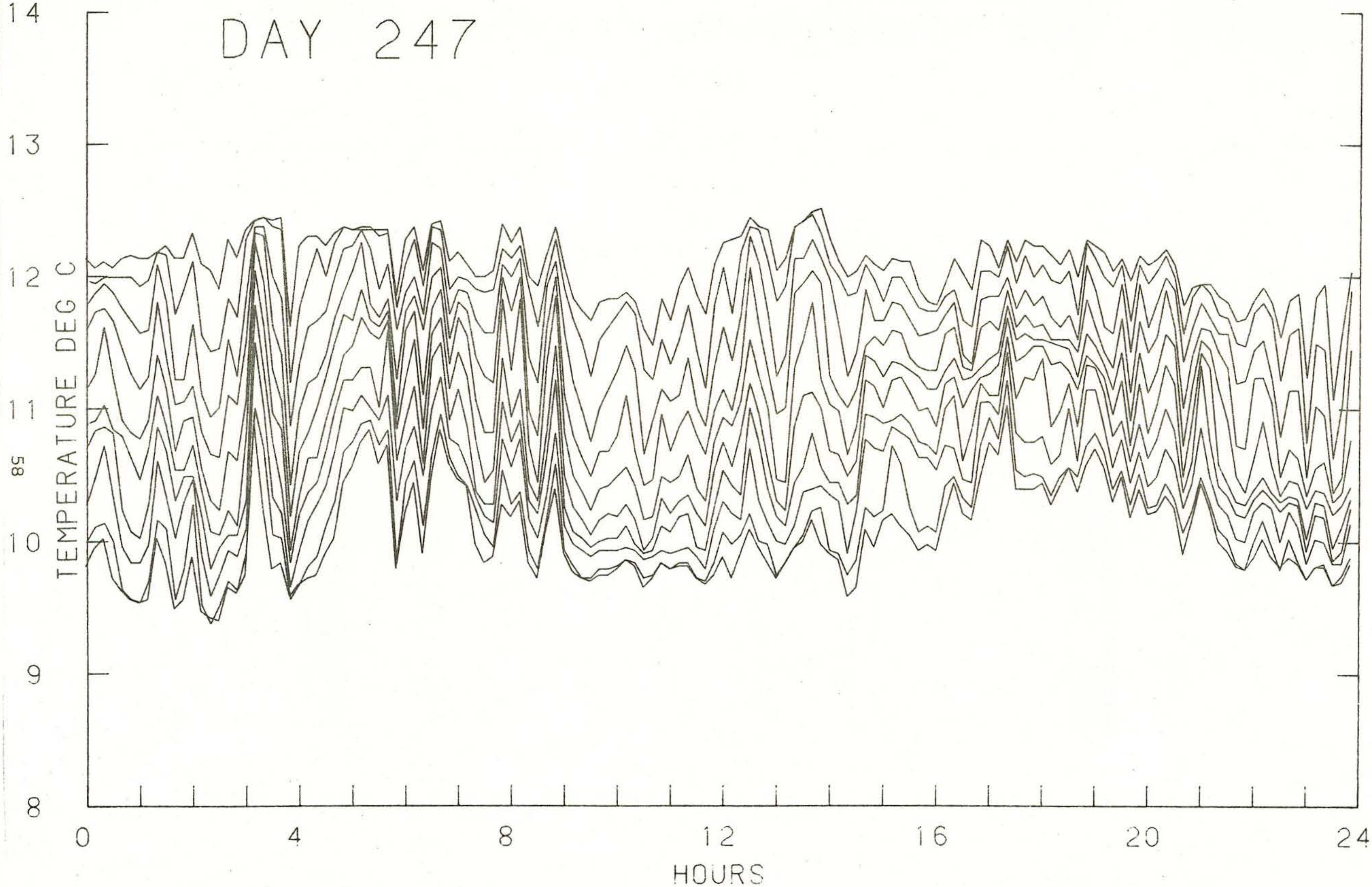

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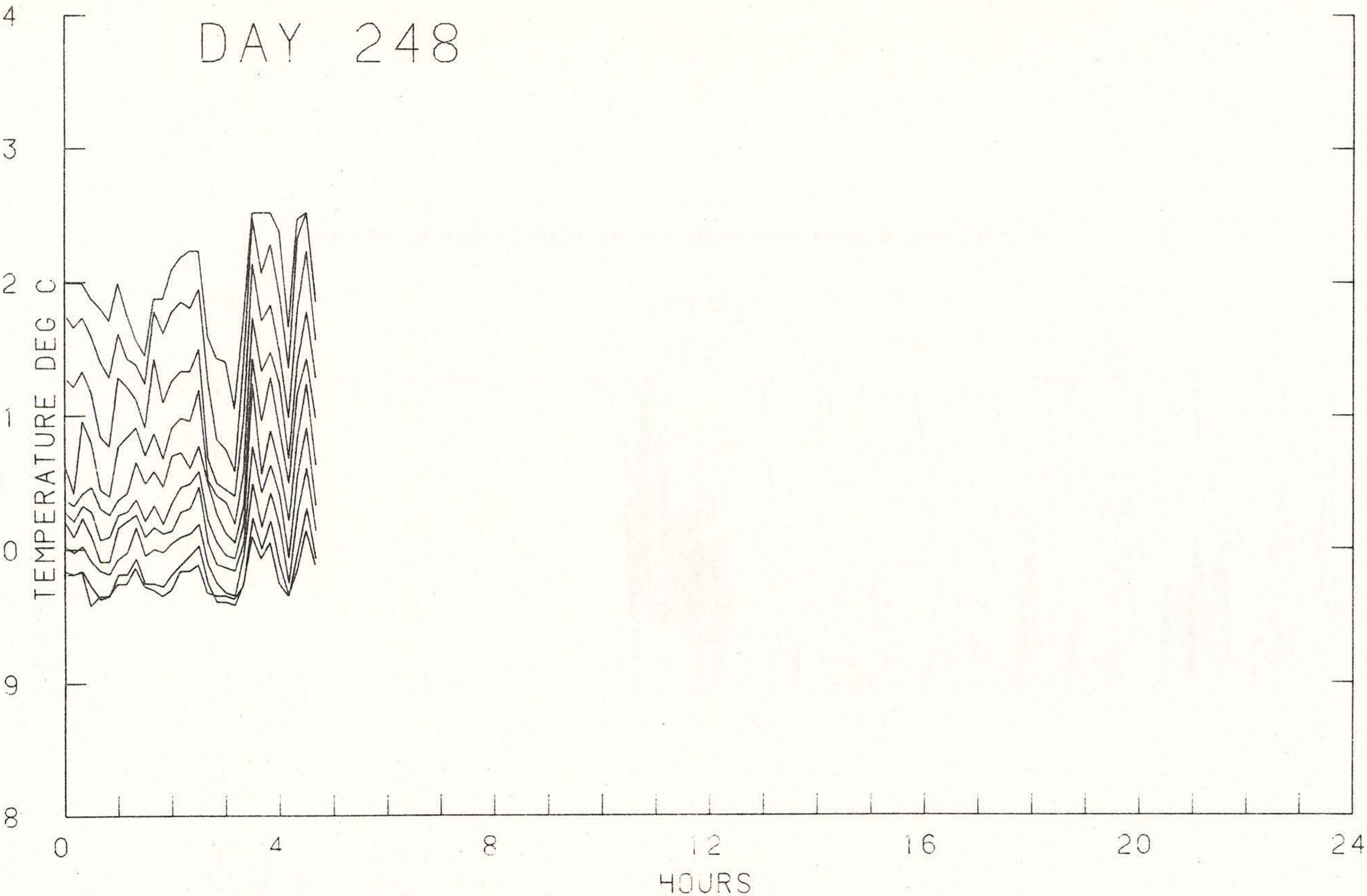

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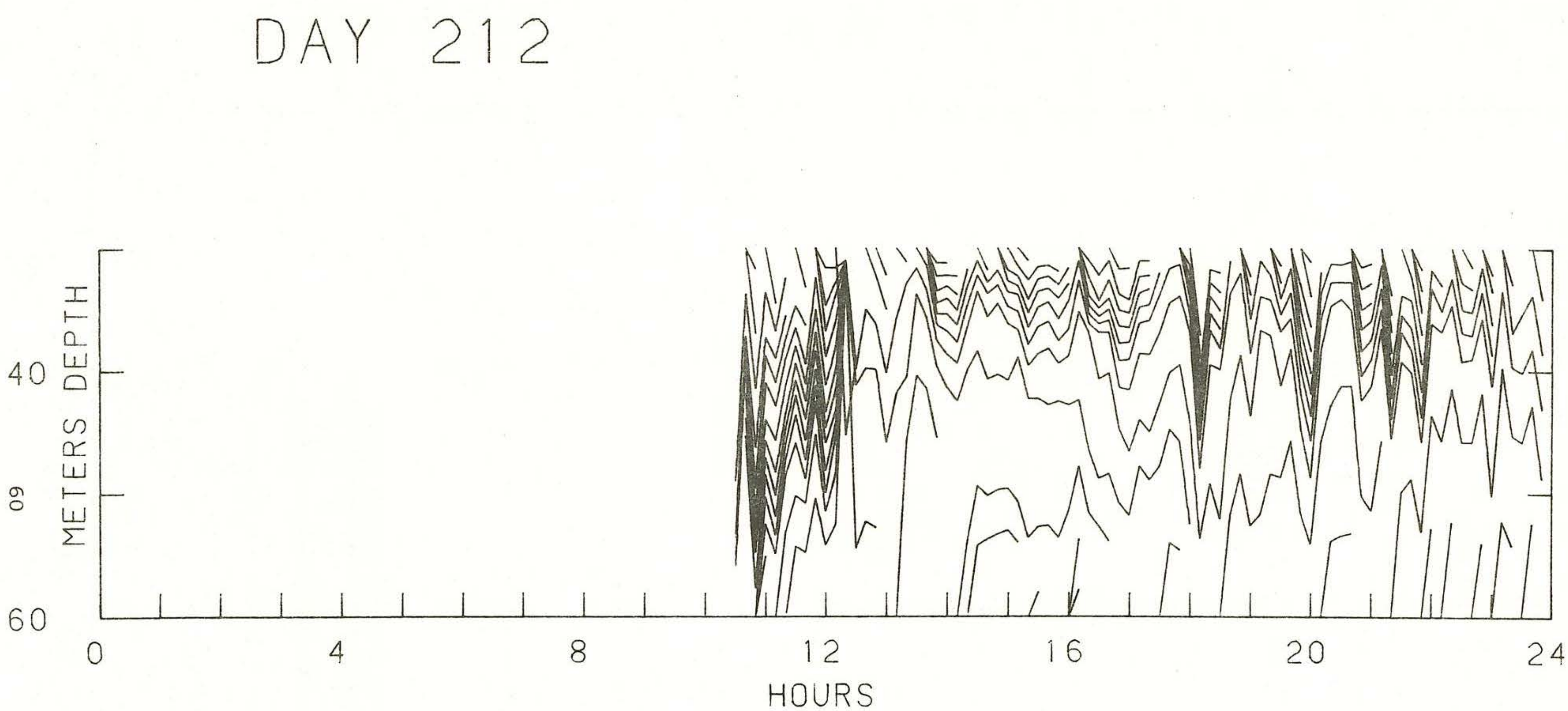


Figure 16. Isotherm depths for .2° increments ranging from 10.0° to 12.8°.

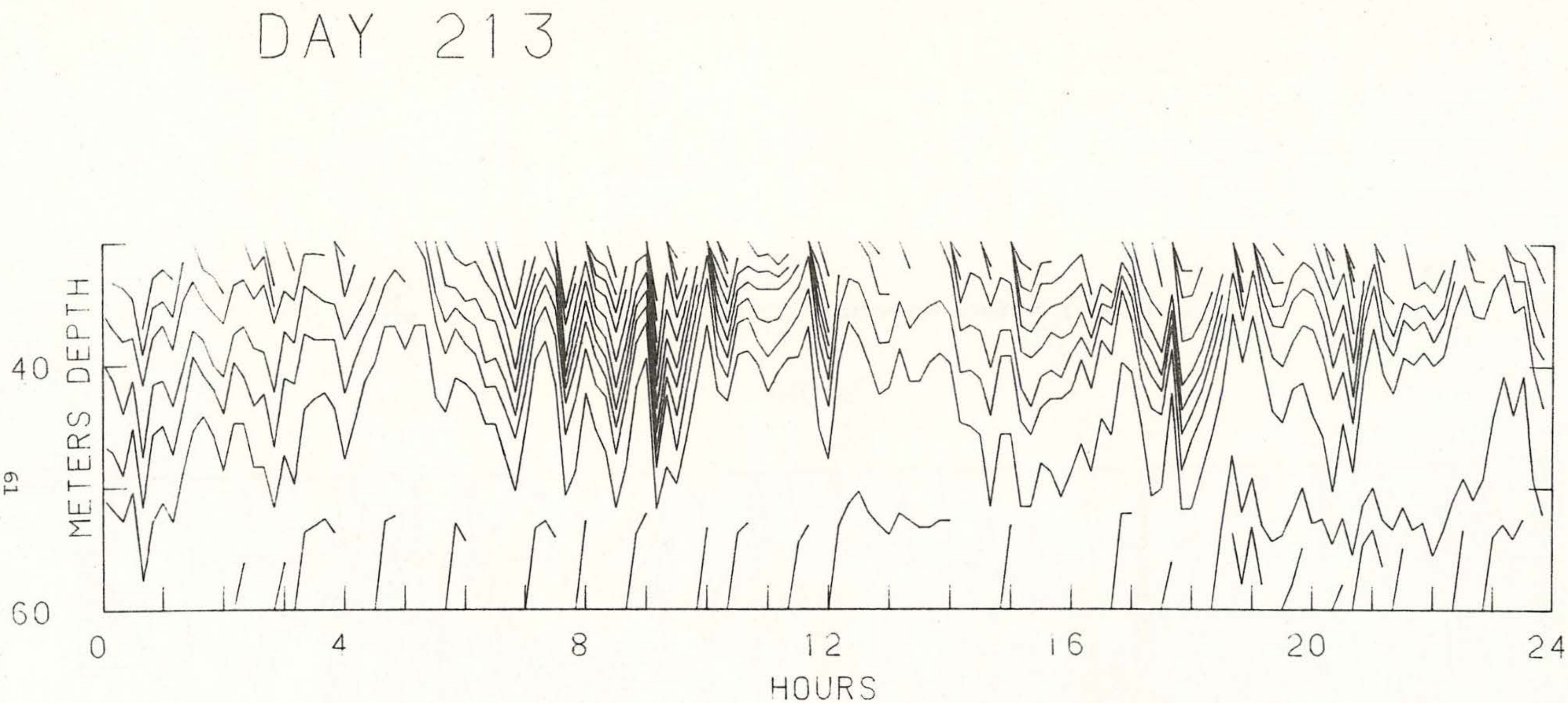


Figure 16. Isotherm depths for .2° increments ranging from 10.0° to 12.2°.

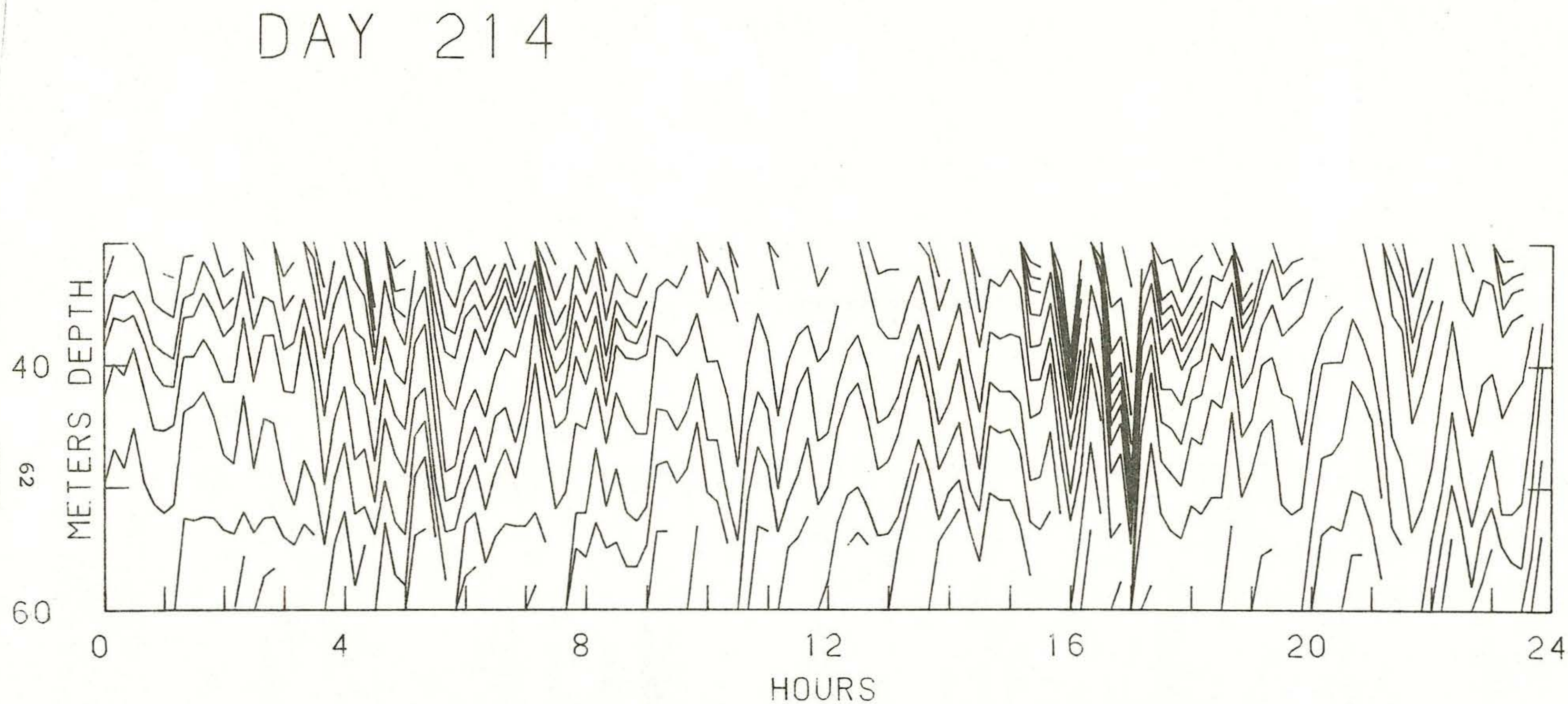


Figure 16. Isotherm depths for .2° increments ranging from 9.6° to 12.2°.

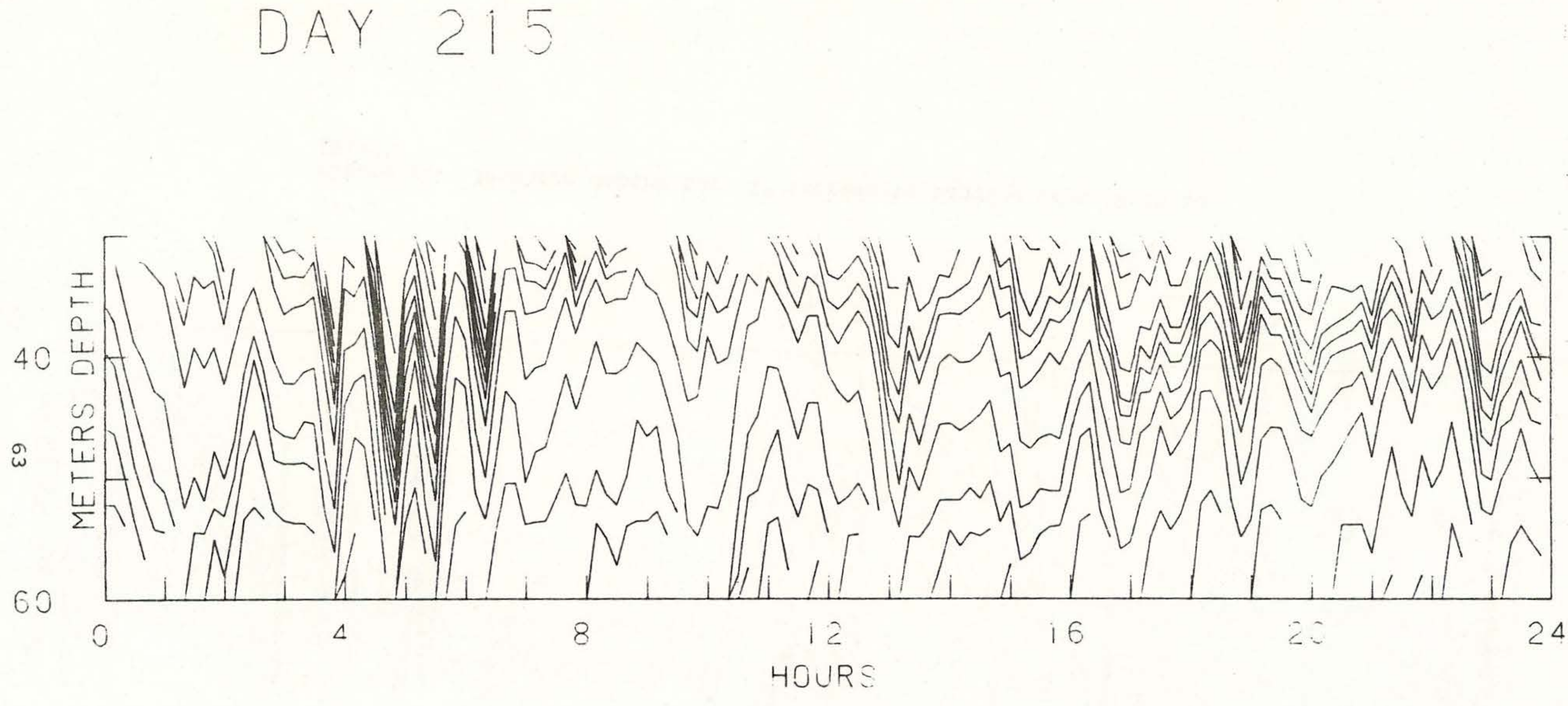


Figure 16. Isotherm depths for .2° increments ranging from 9.8° to 12.0°.

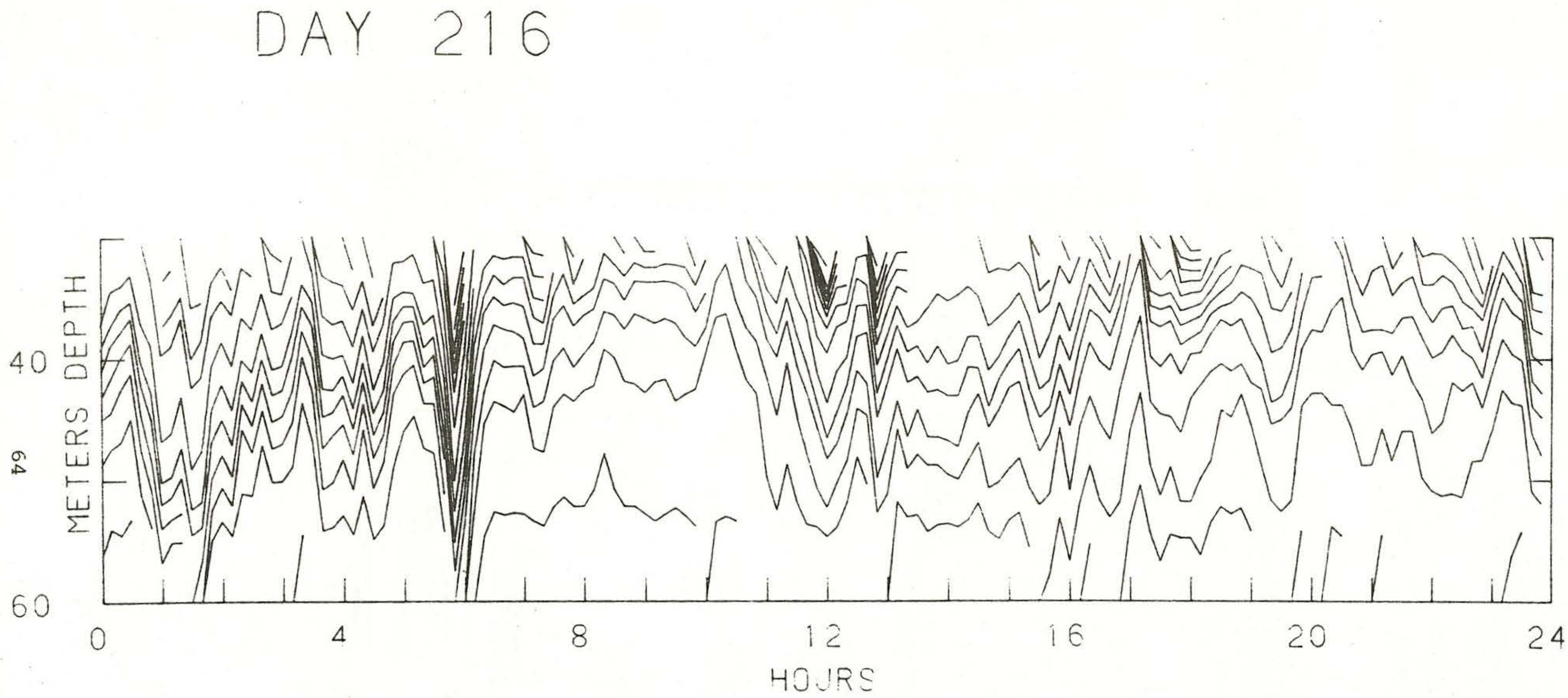


Figure 16. Isotherm depths for .2° increments ranging from 10.2° to 12.4°.

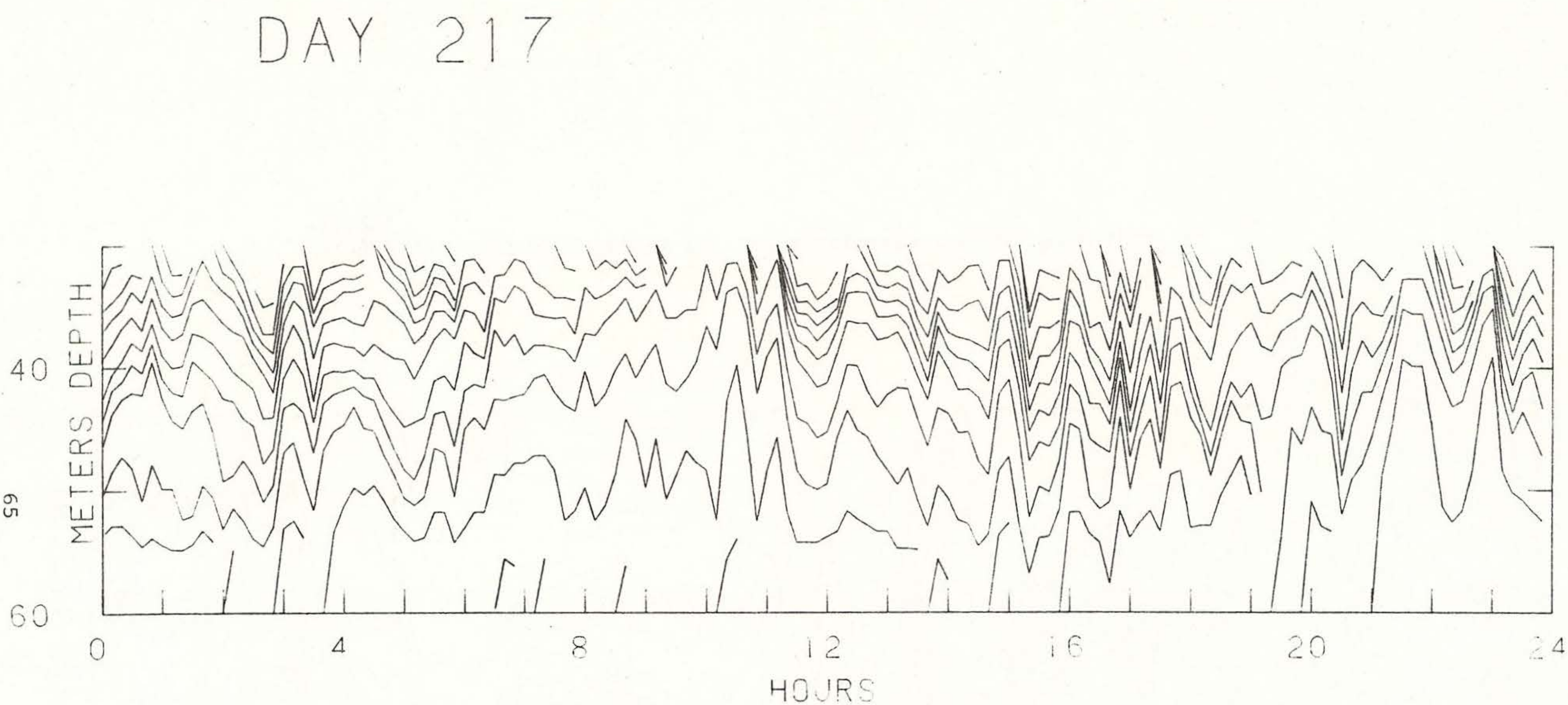


Figure 16. Isotherm depths for .2° increments ranging from 10.2° to 12.2°.

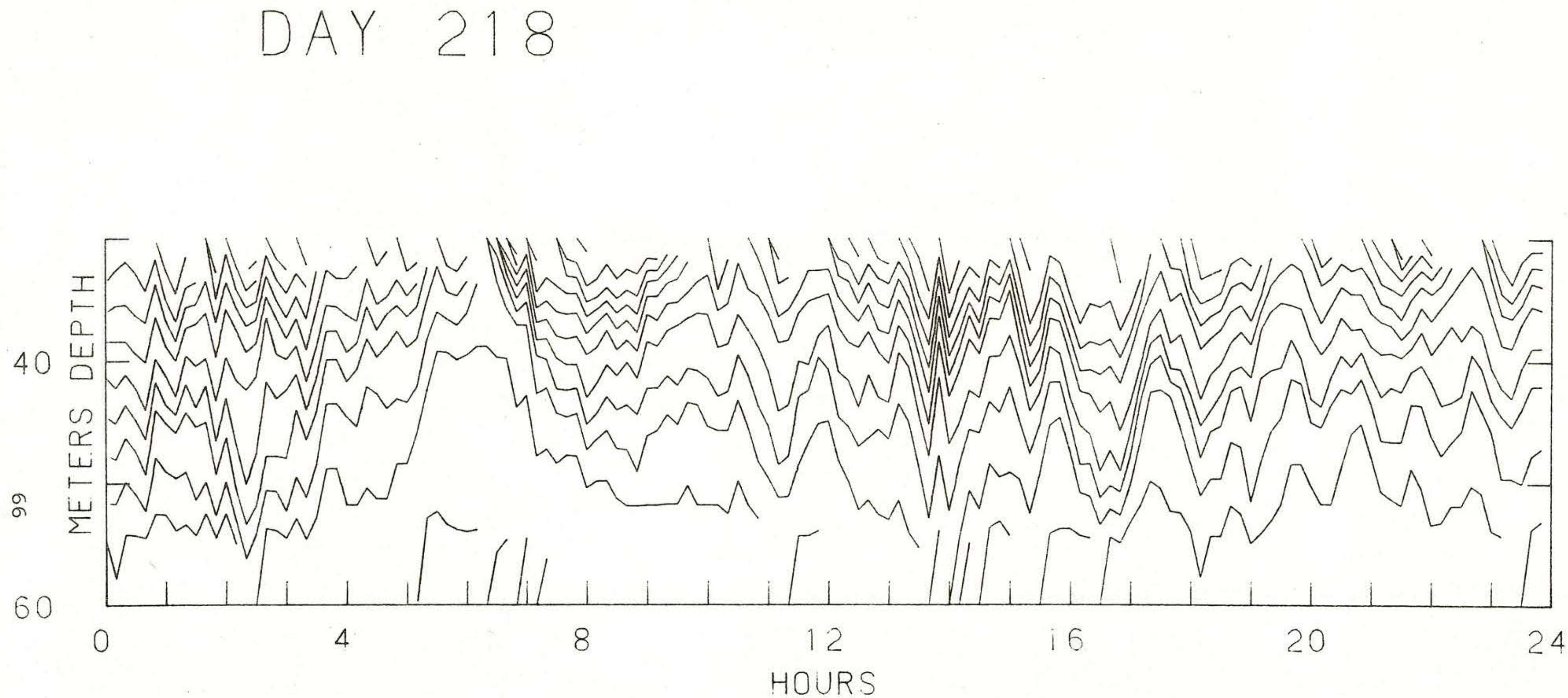


Figure 16. Isotherm depths for .2° increments ranging from 10.2° to 12.2°.

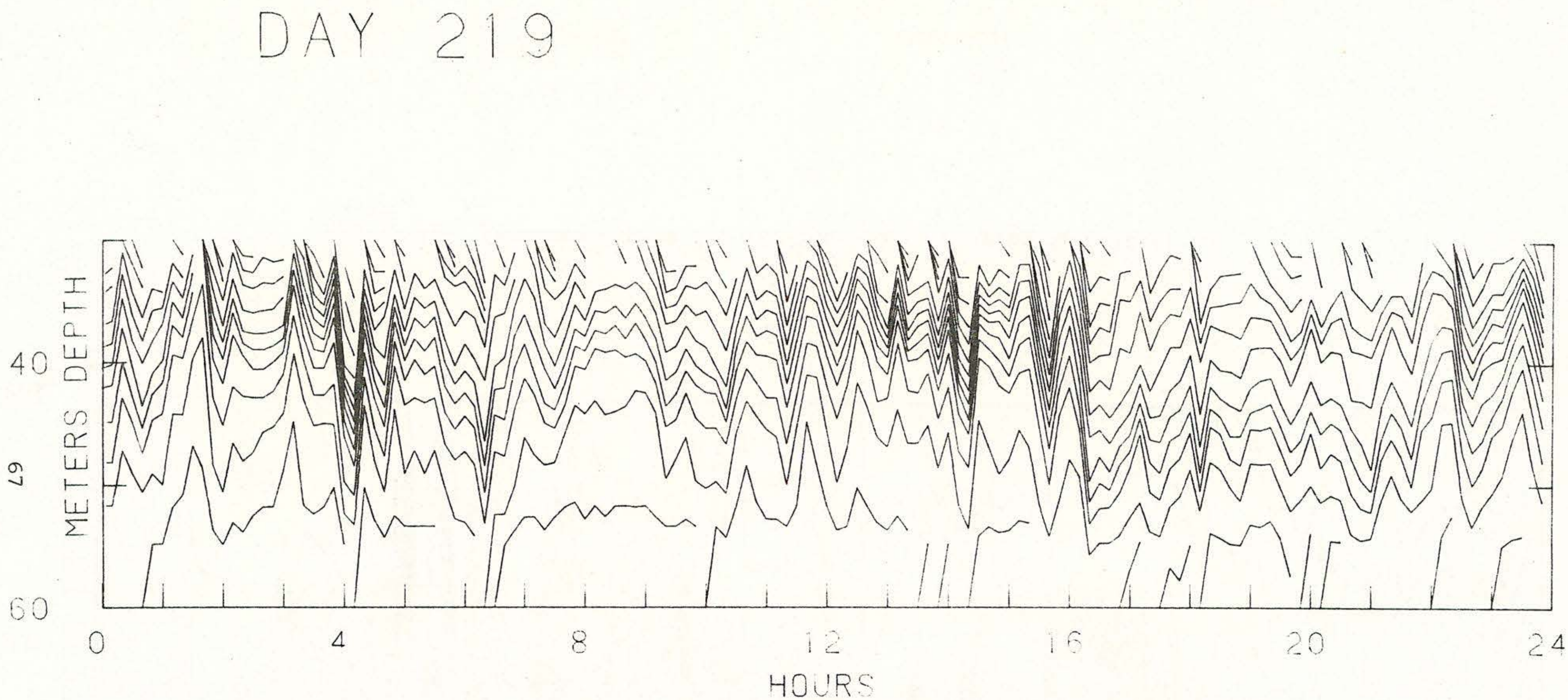


Figure 16. Isotherm depths for .2° increments ranging from 10.4° to 12.8°.

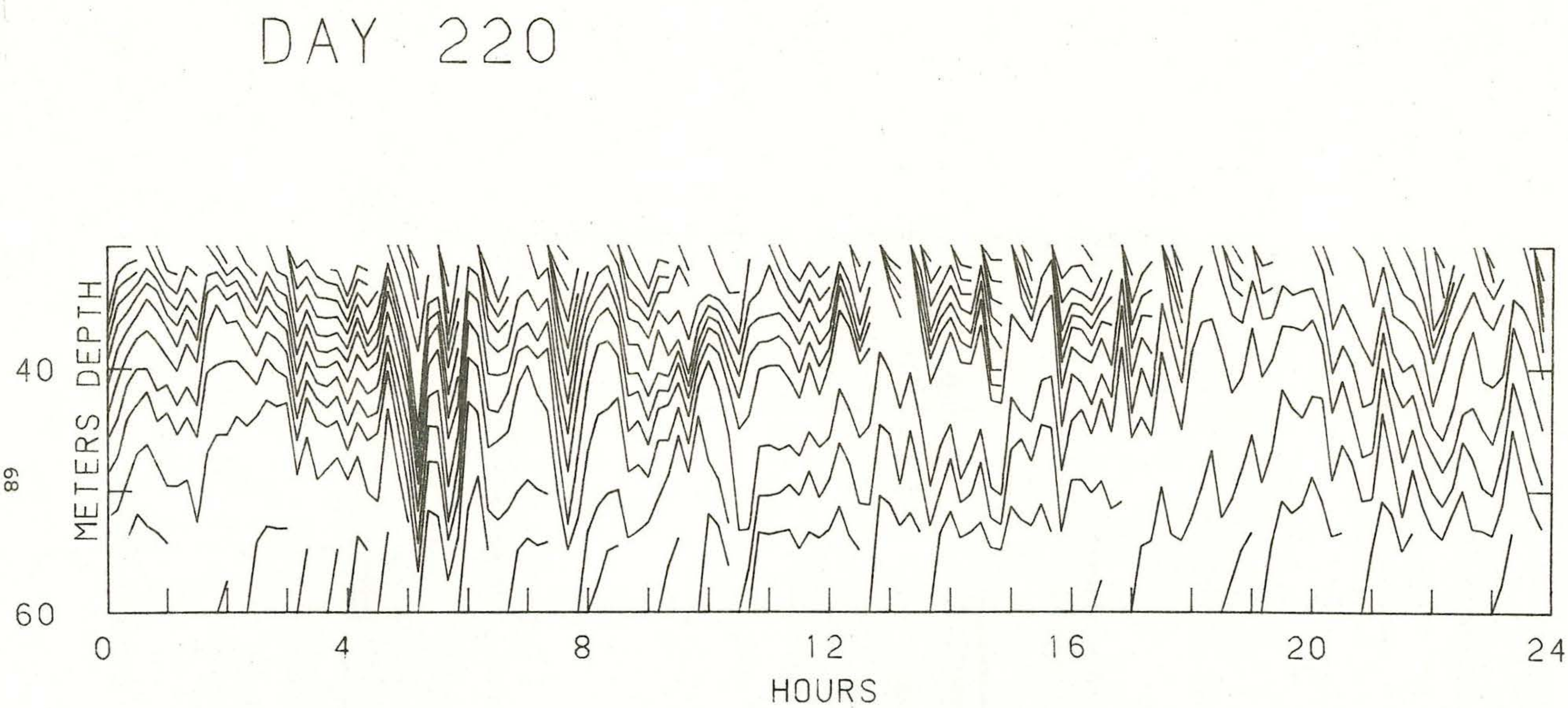


Figure 16. Isotherm depths for .2° increments ranging from 10.4° to 12.8°.

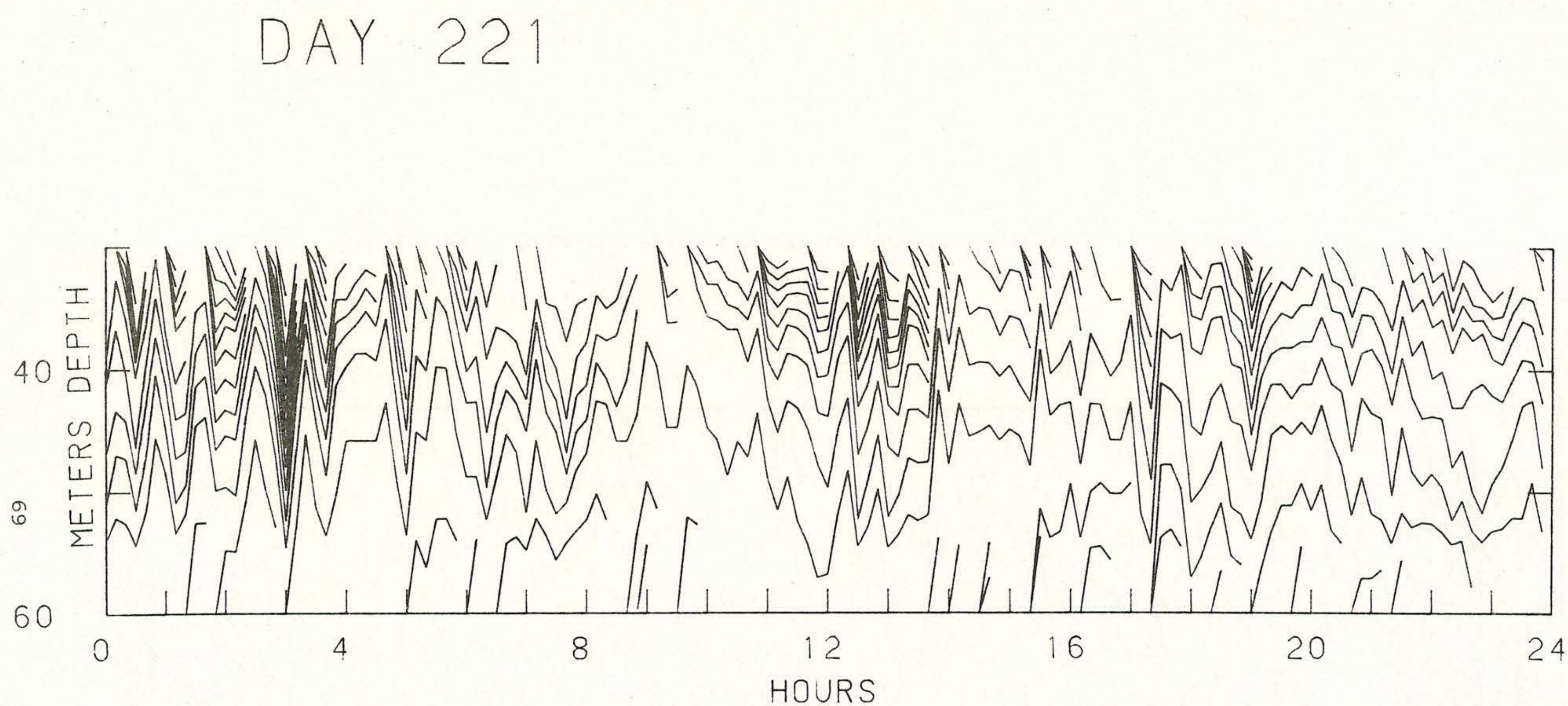


Figure 16. Isotherm depths for .2° increments ranging from 10.0° to 12.8°.

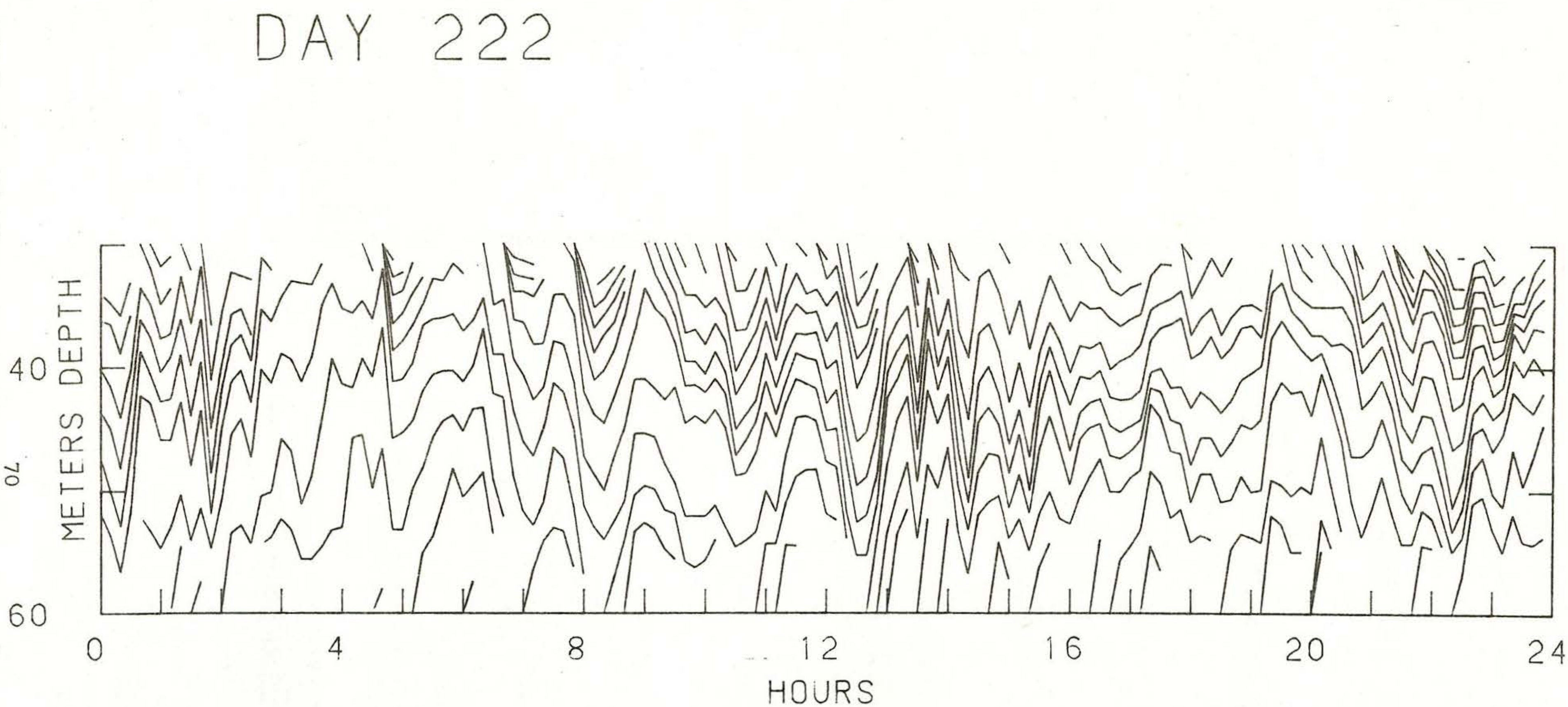


Figure 16. Isotherm depths for .2° increments ranging from 9.8° to 12.6°.

Figure 16. Isotherm depths for .2° increments ranging from 10.0° to 12.8°.

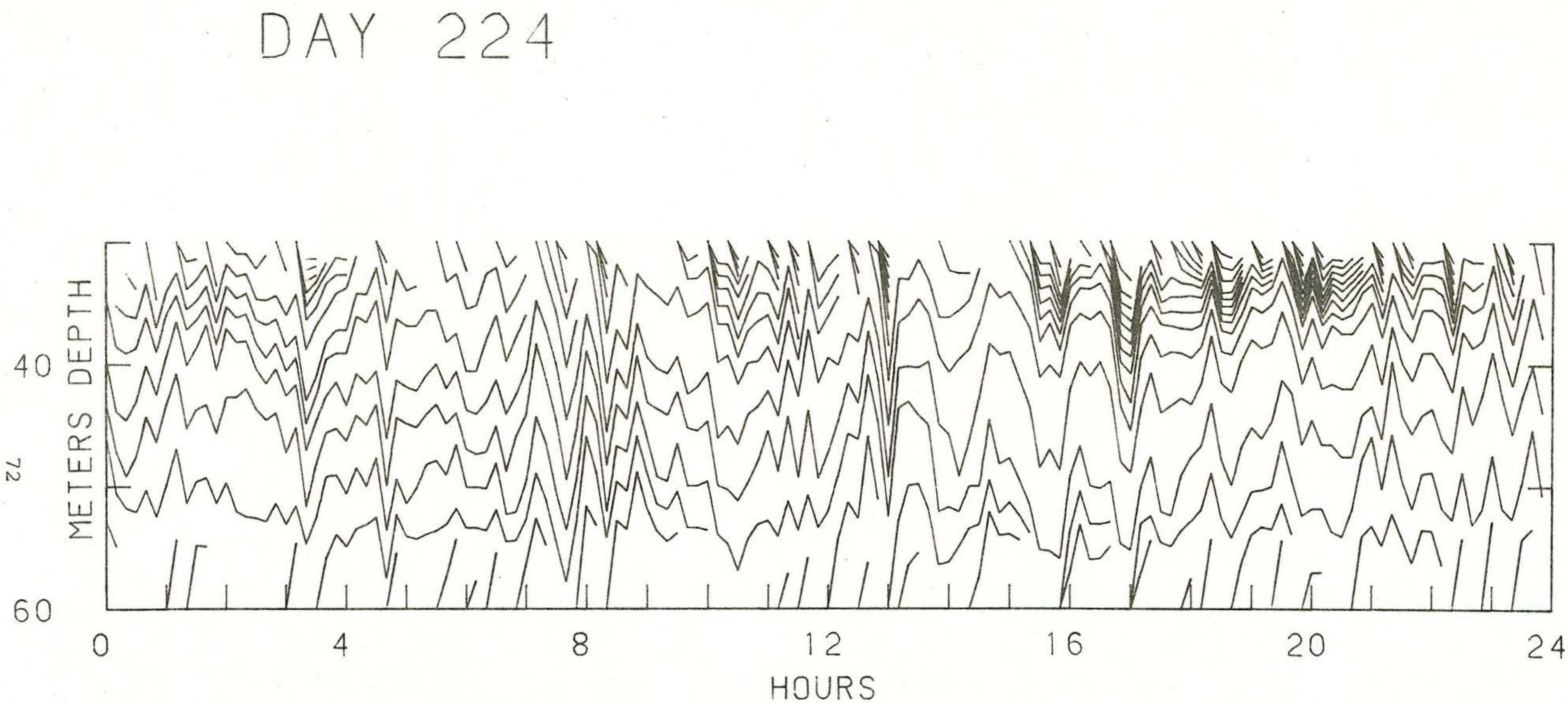
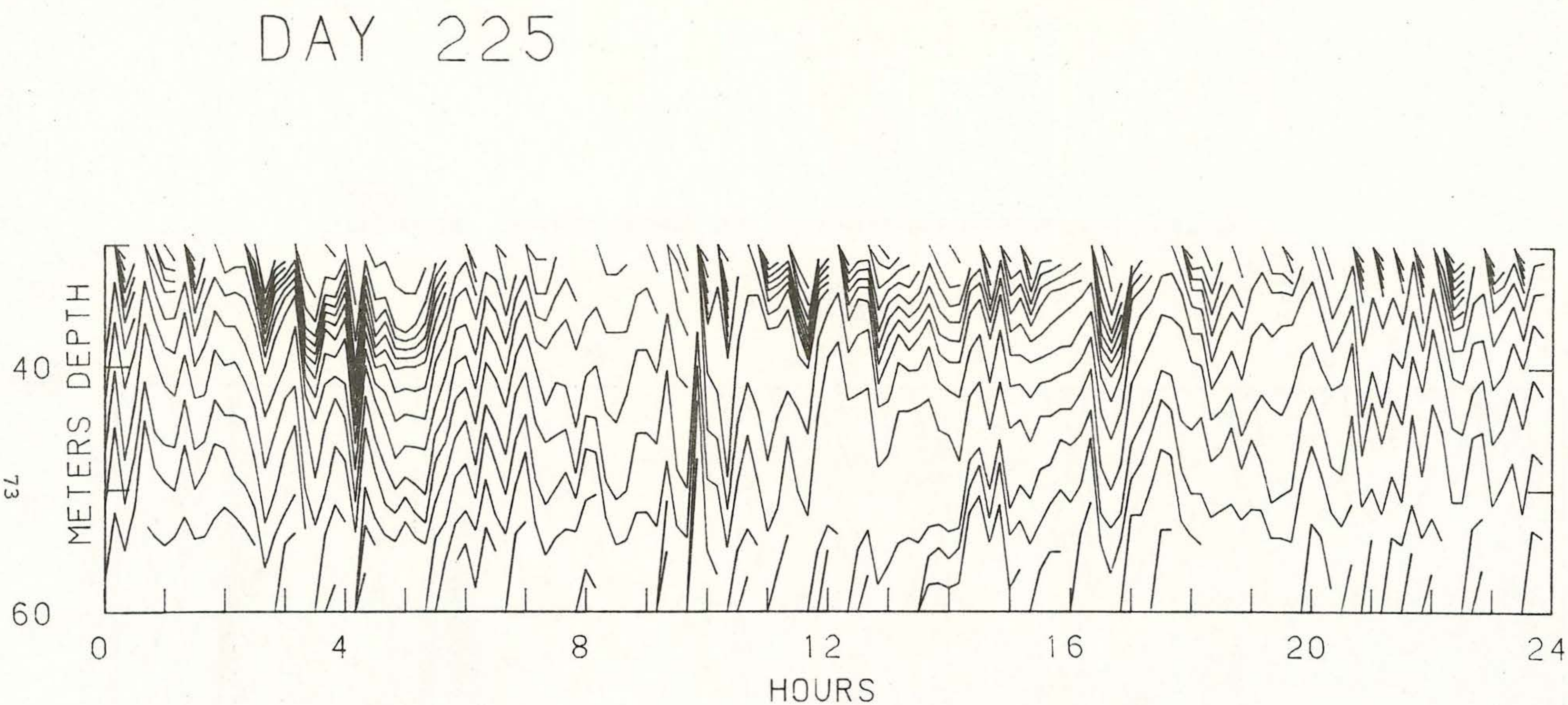


Figure 16. Isotherm depths for .2° increments ranging from 10.2° to 12.8°.



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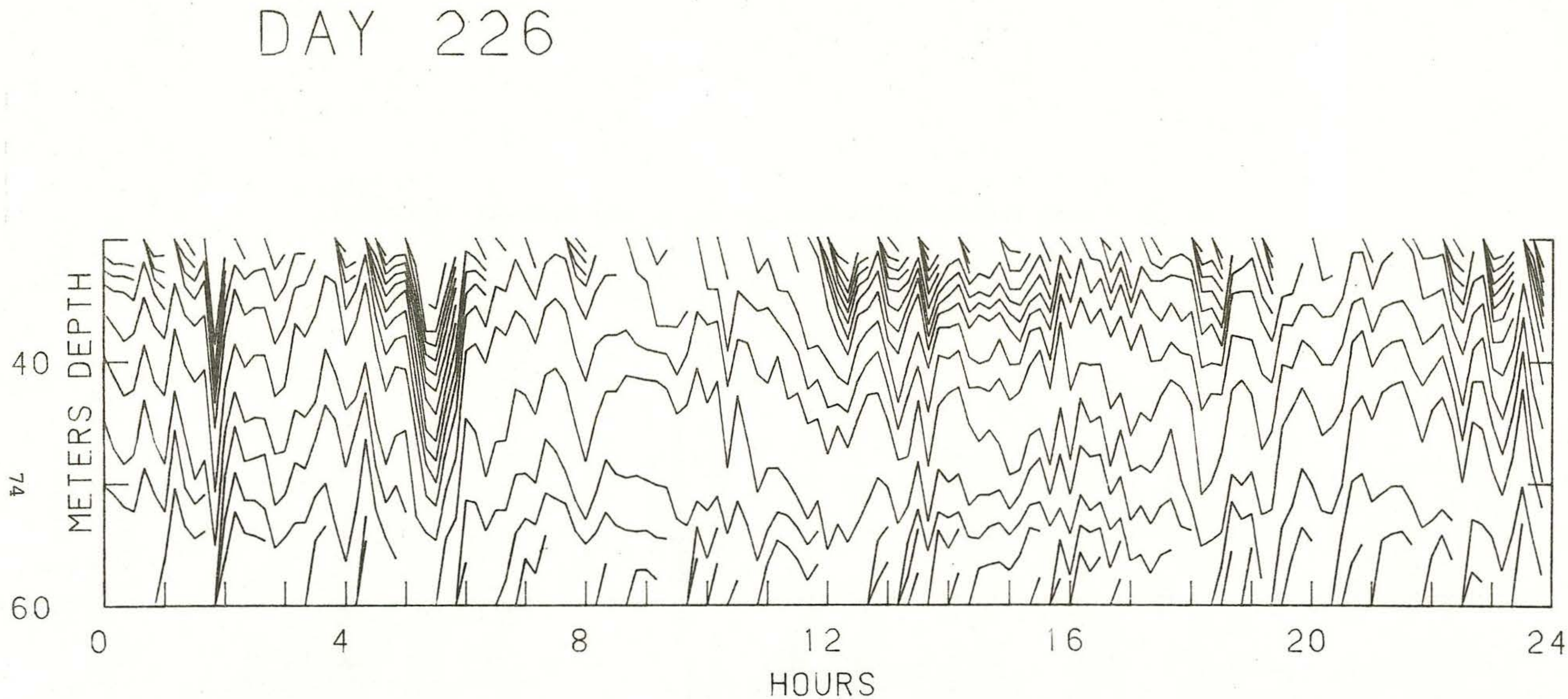

Figure 16. Isotherm depths for .2° increments ranging from 10.0° to 12.8°.

Figure 16. Isotherm depths for .2° increments ranging from 10.2° to 12.8°.

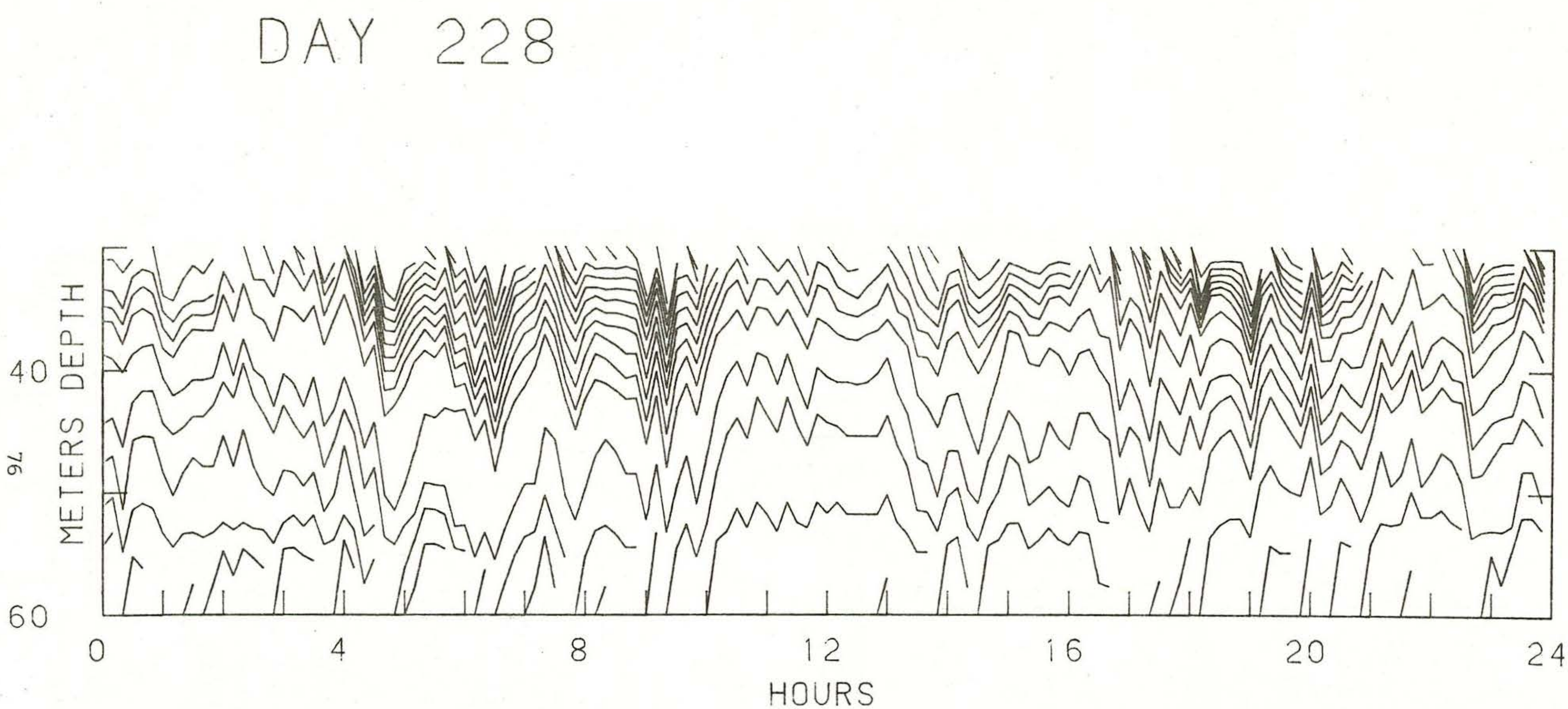

Figure 16. Isotherm depths for .2° increments ranging from 10.2° to 13.0°.

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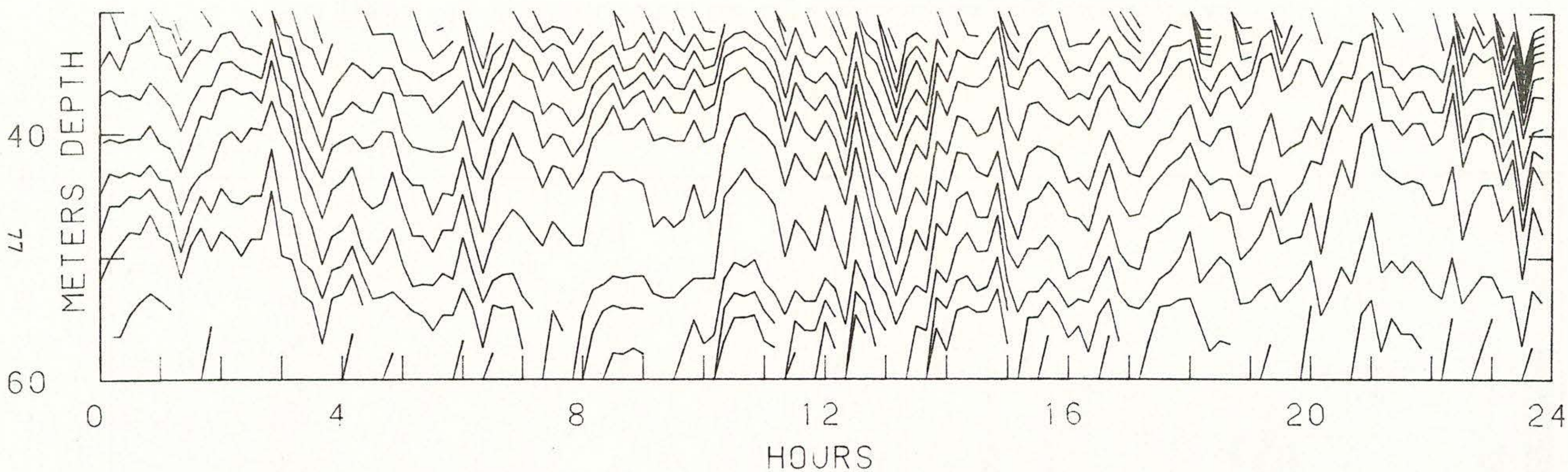


Figure 16. Isotherm depths for .2° increments ranging from 10.2° to 12.8°.

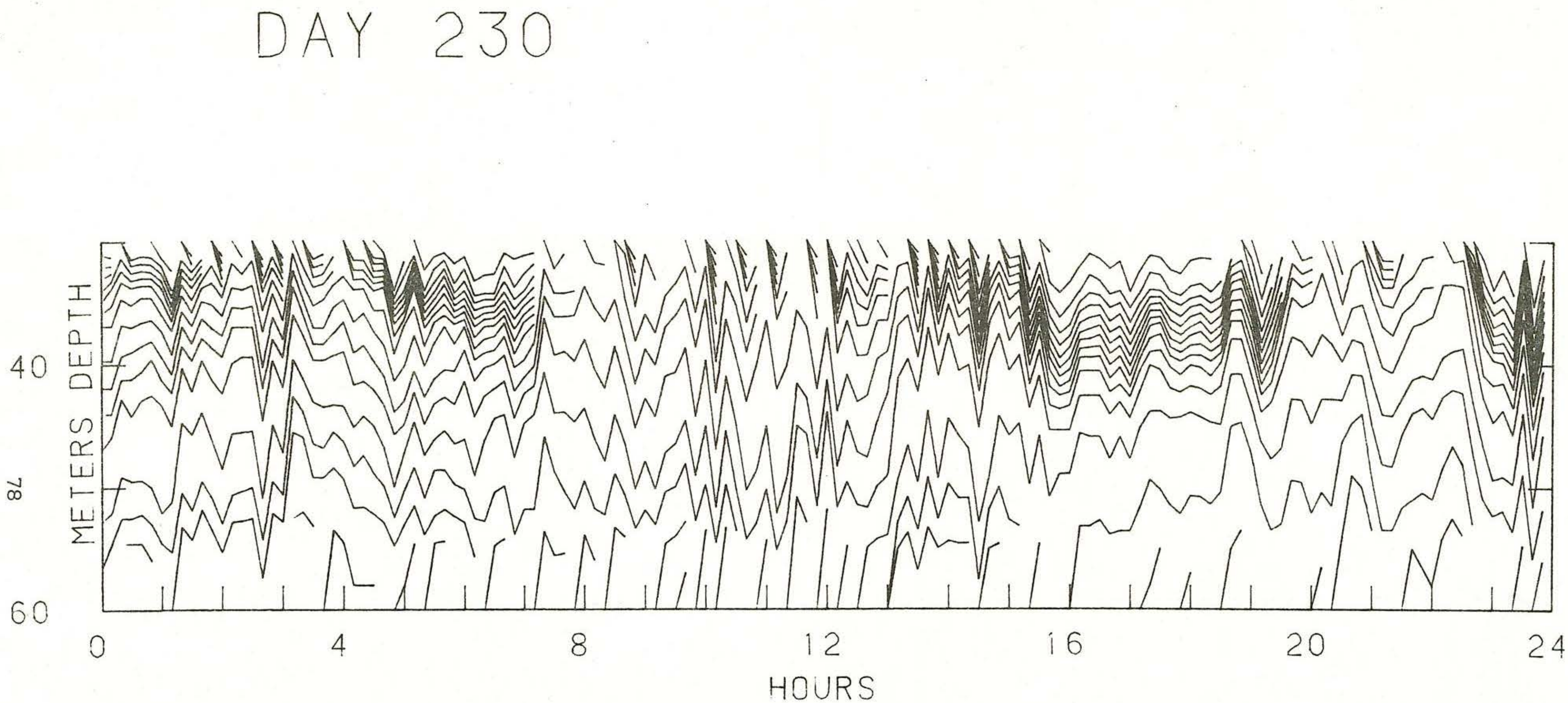


Figure 16. Isotherm depths for .2° increments ranging from 10.0° to 12.8°.

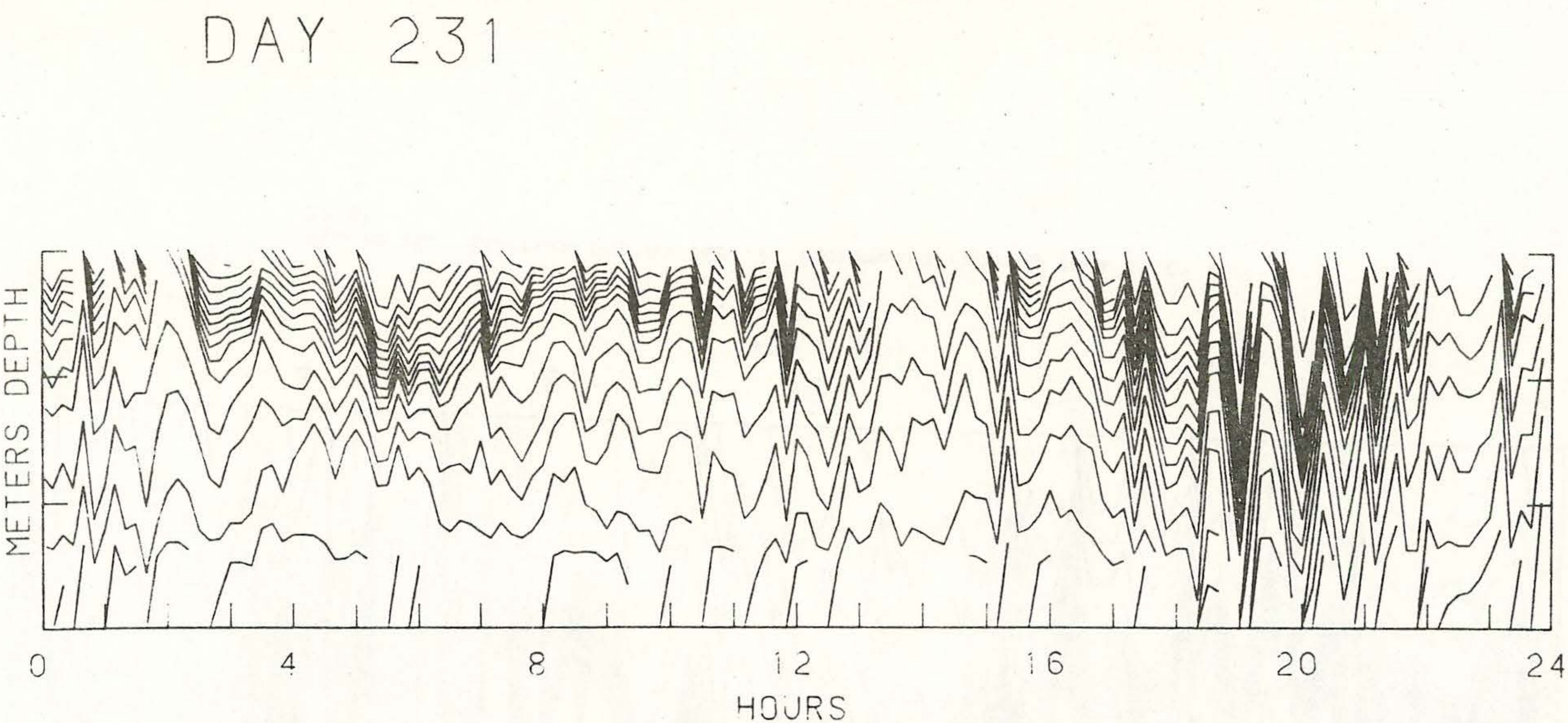


Figure 16. Isotherm depths for .2° increments ranging from 9.8° to 12.6°.

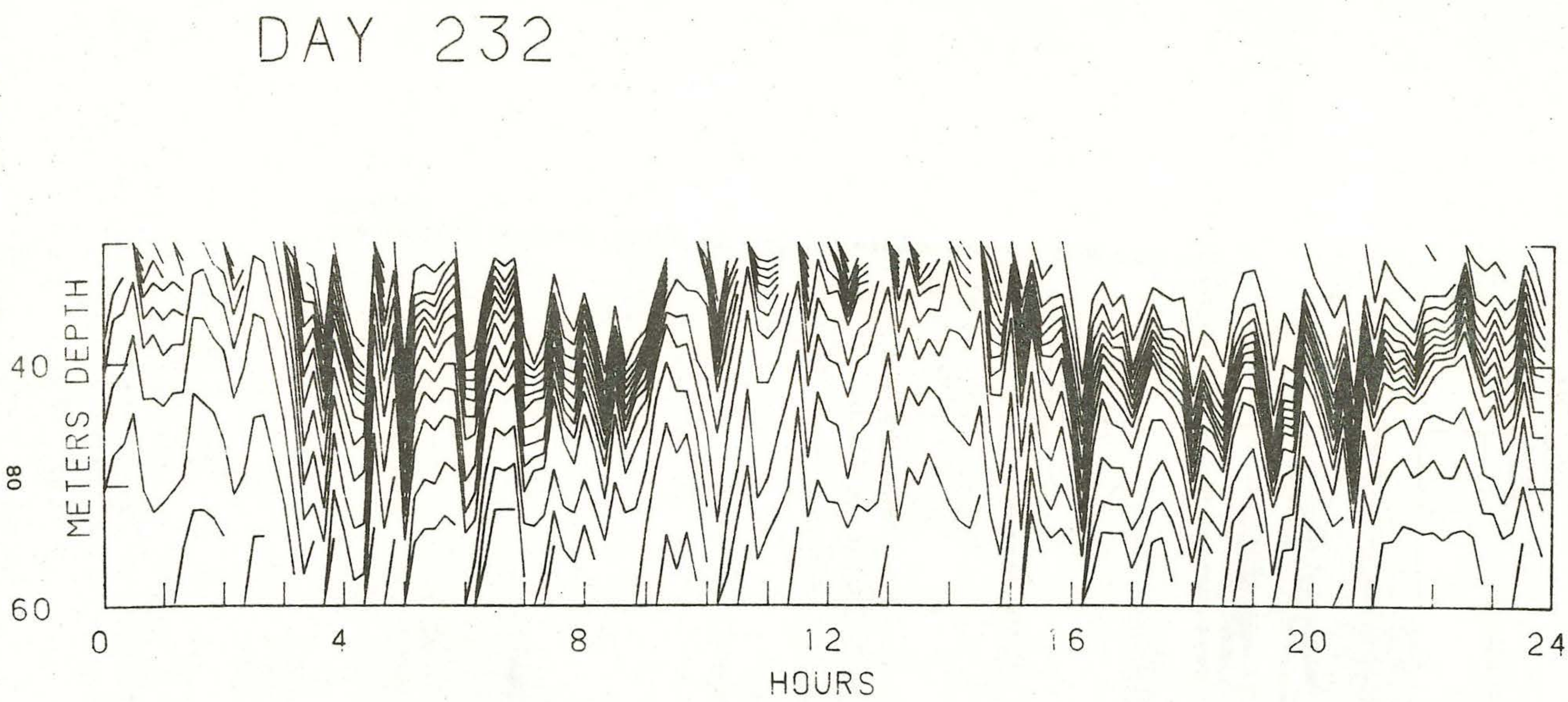


Figure 16. Isotherm depths for .2° increments ranging from 10.0° to 12.4°.

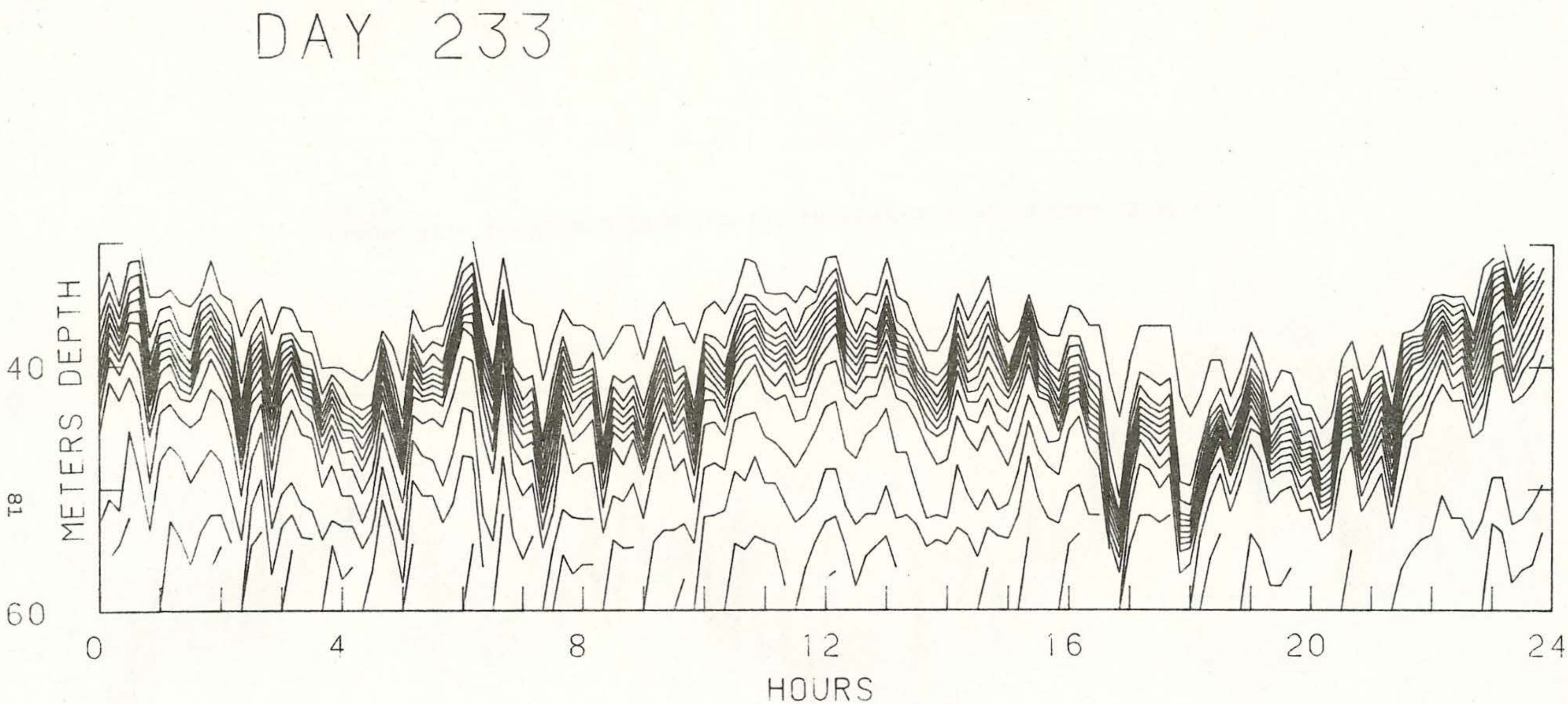


Figure 16. Isotherm depths for .2° increments ranging from 10.0° to 12.4°.

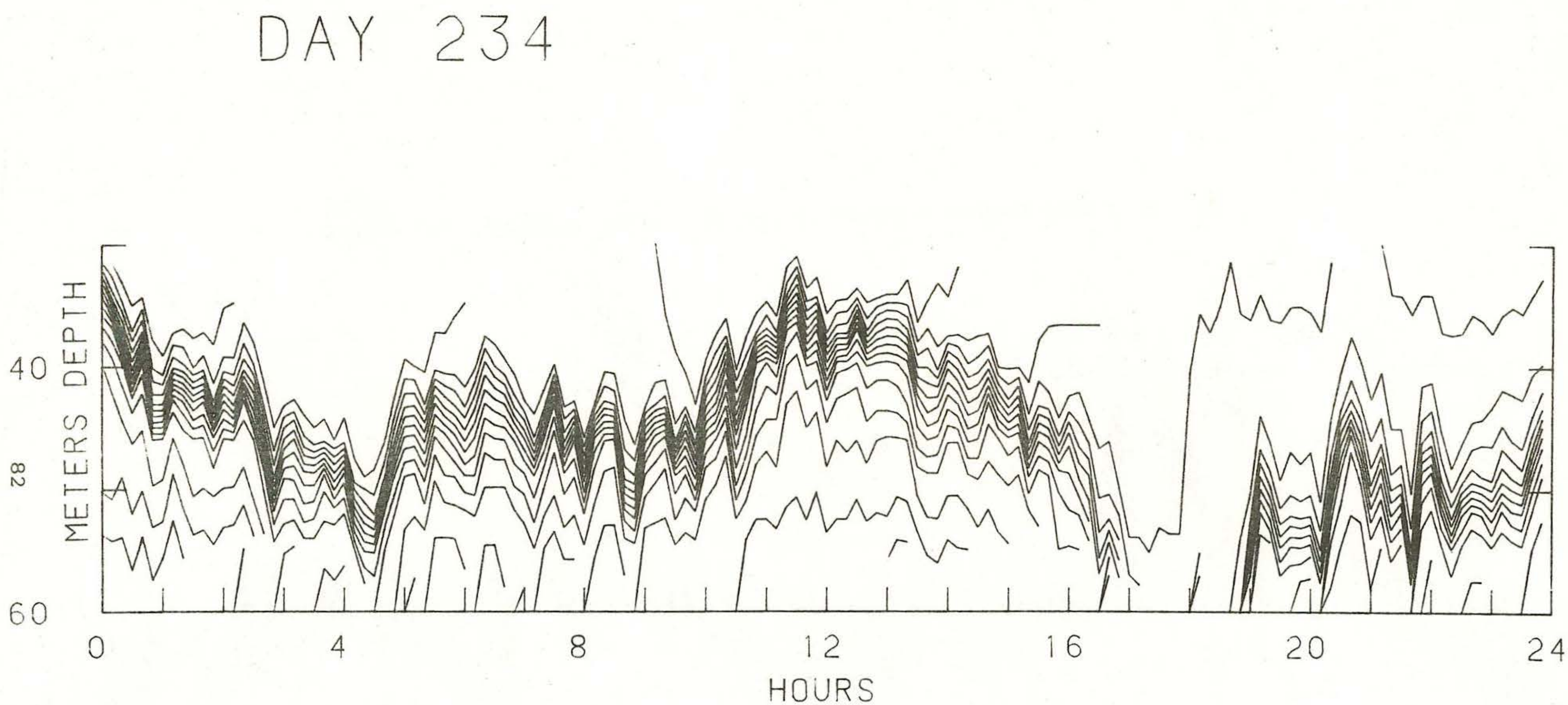


Figure 16. Isotherm depths for .2° increments ranging from 9.8° to 12.4°.

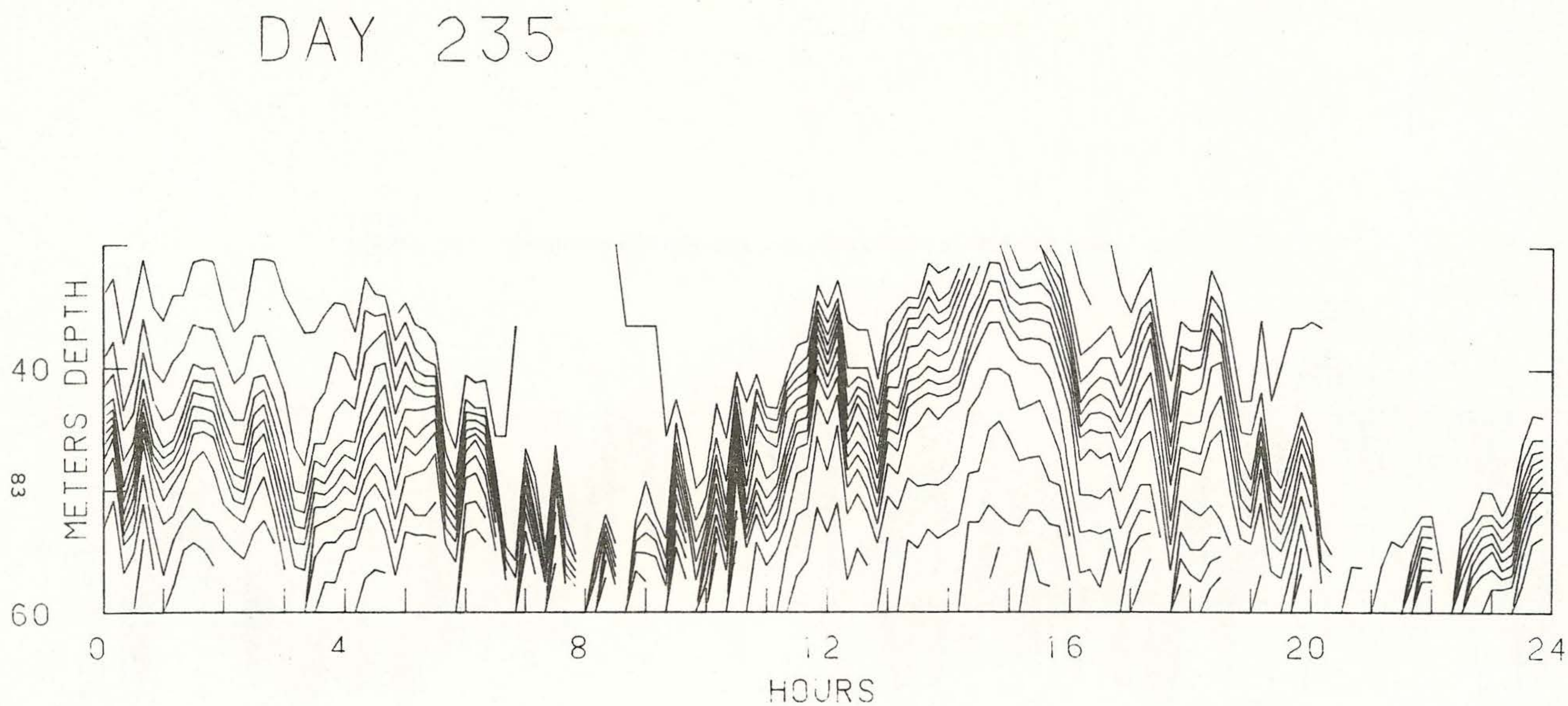


Figure 16. Isotherm depths for .2° increments ranging from 9.4° to 12.0°.

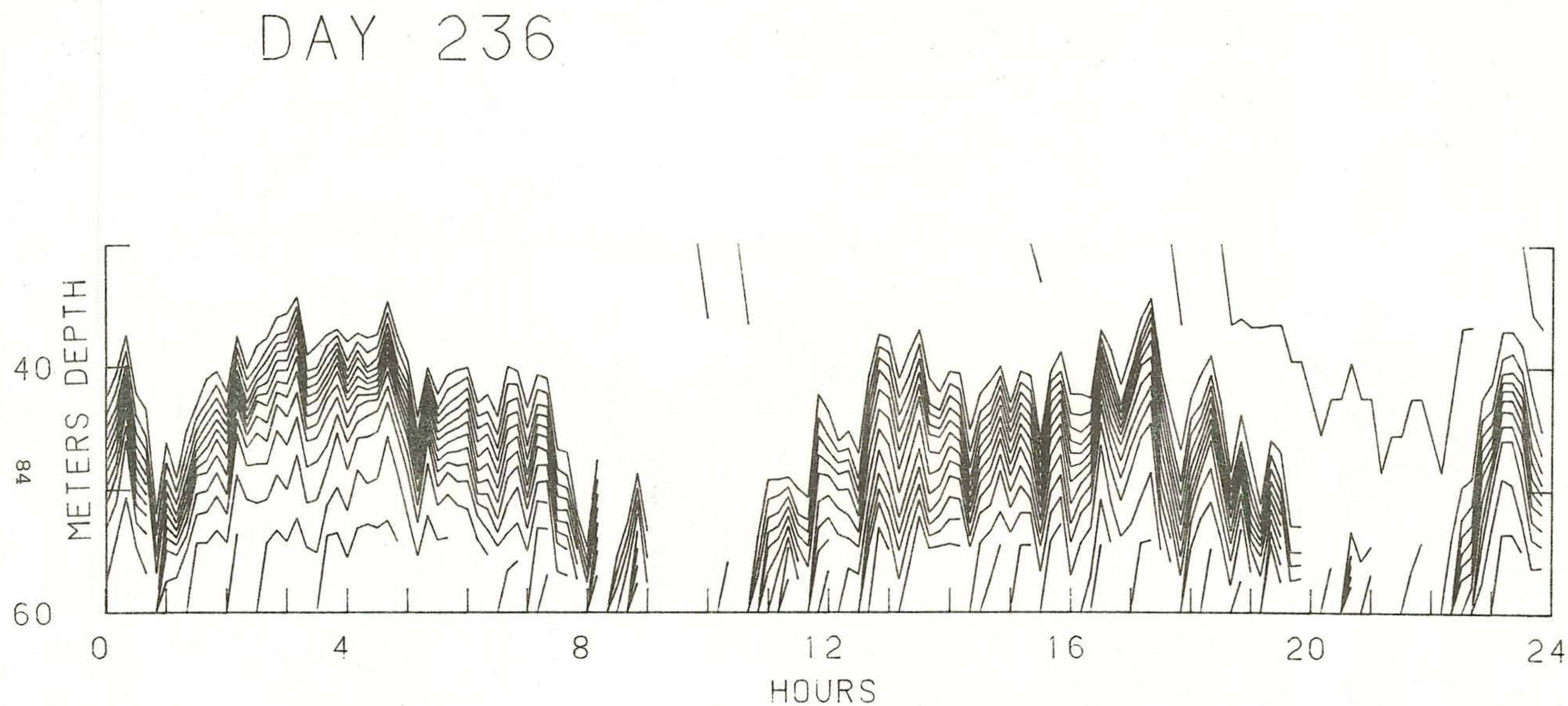


Figure 16. Isotherm depths for .2° increments ranging from 9.4° to 12.0°.

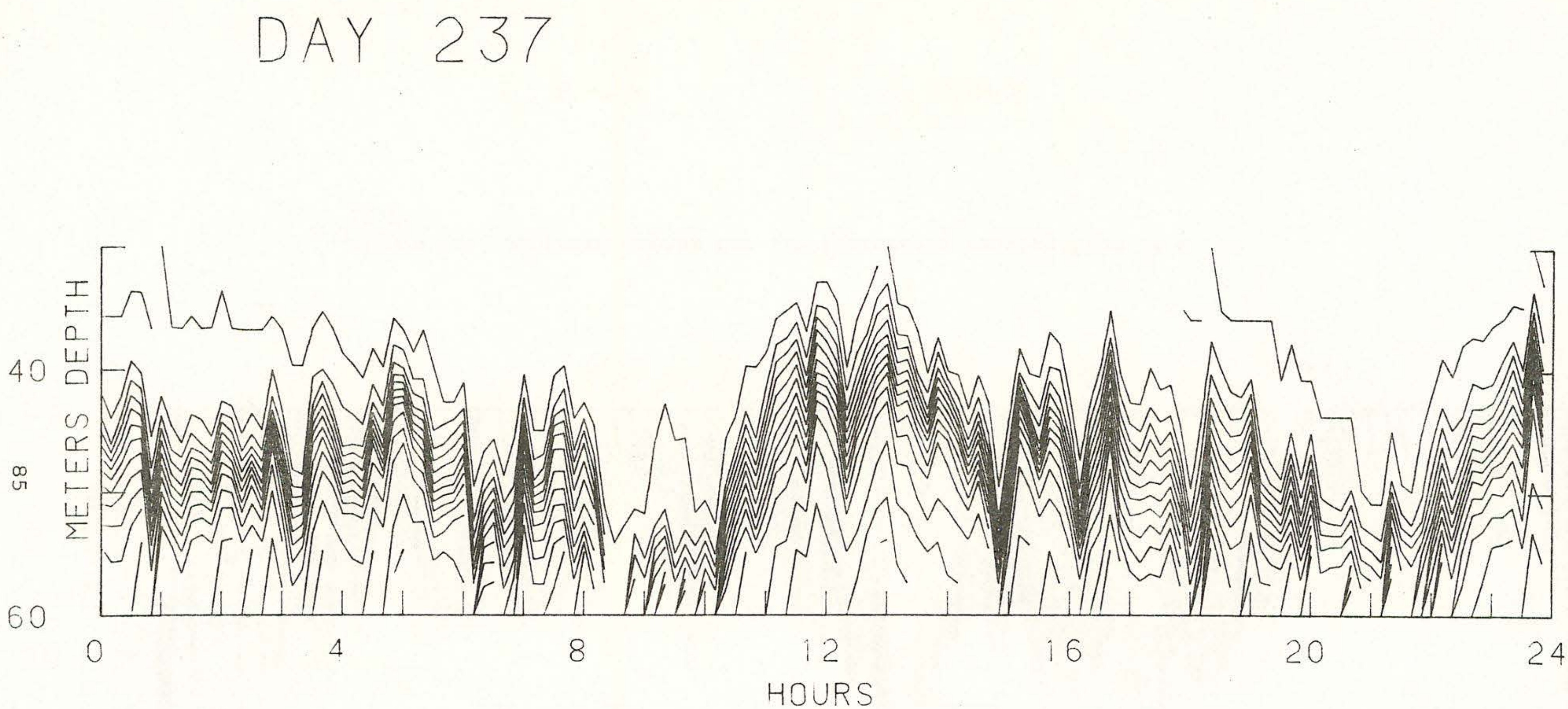


Figure 16. Isotherm depths for .2° increments ranging from 9.6° to 12.2°.

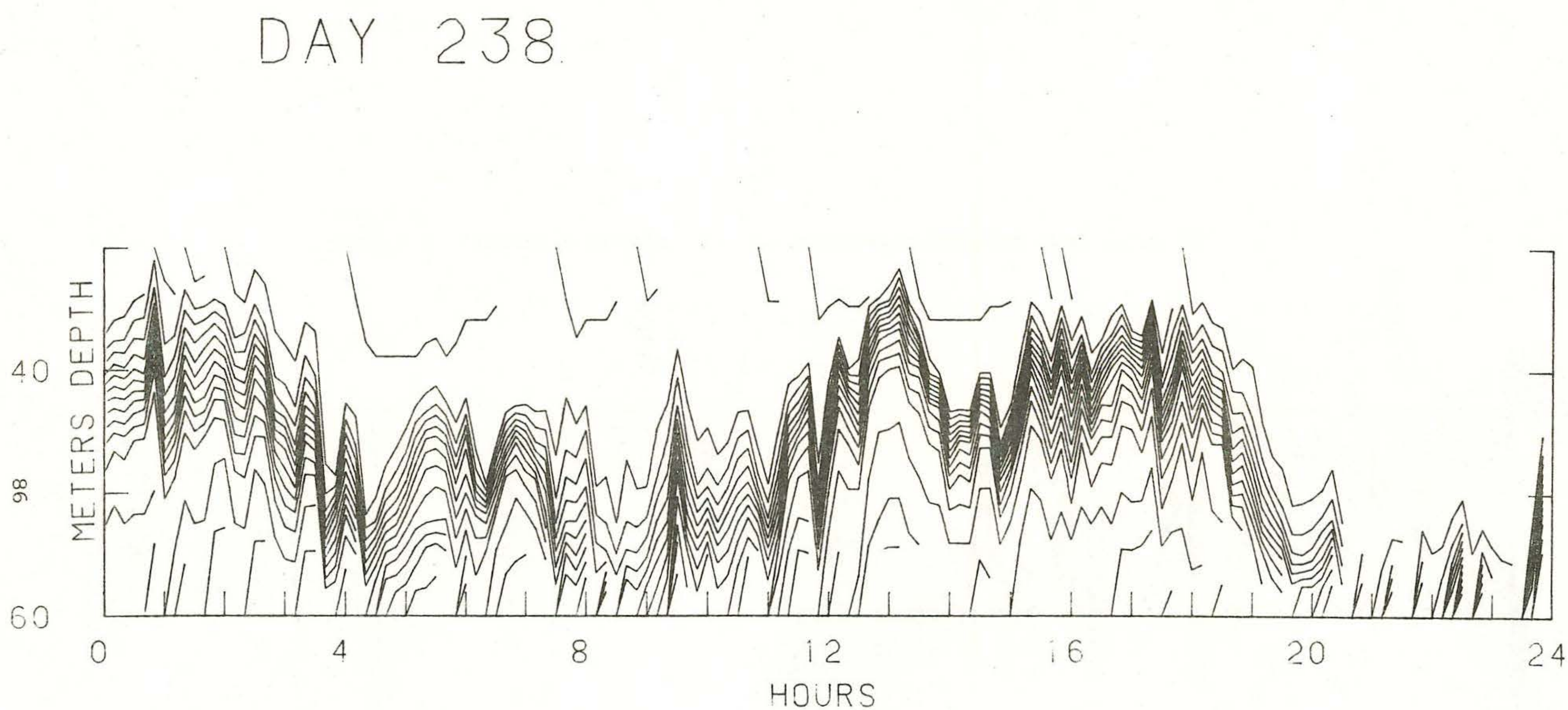


Figure 16. Isotherm depths for .2° increments ranging from 9.4° to 12.2°.

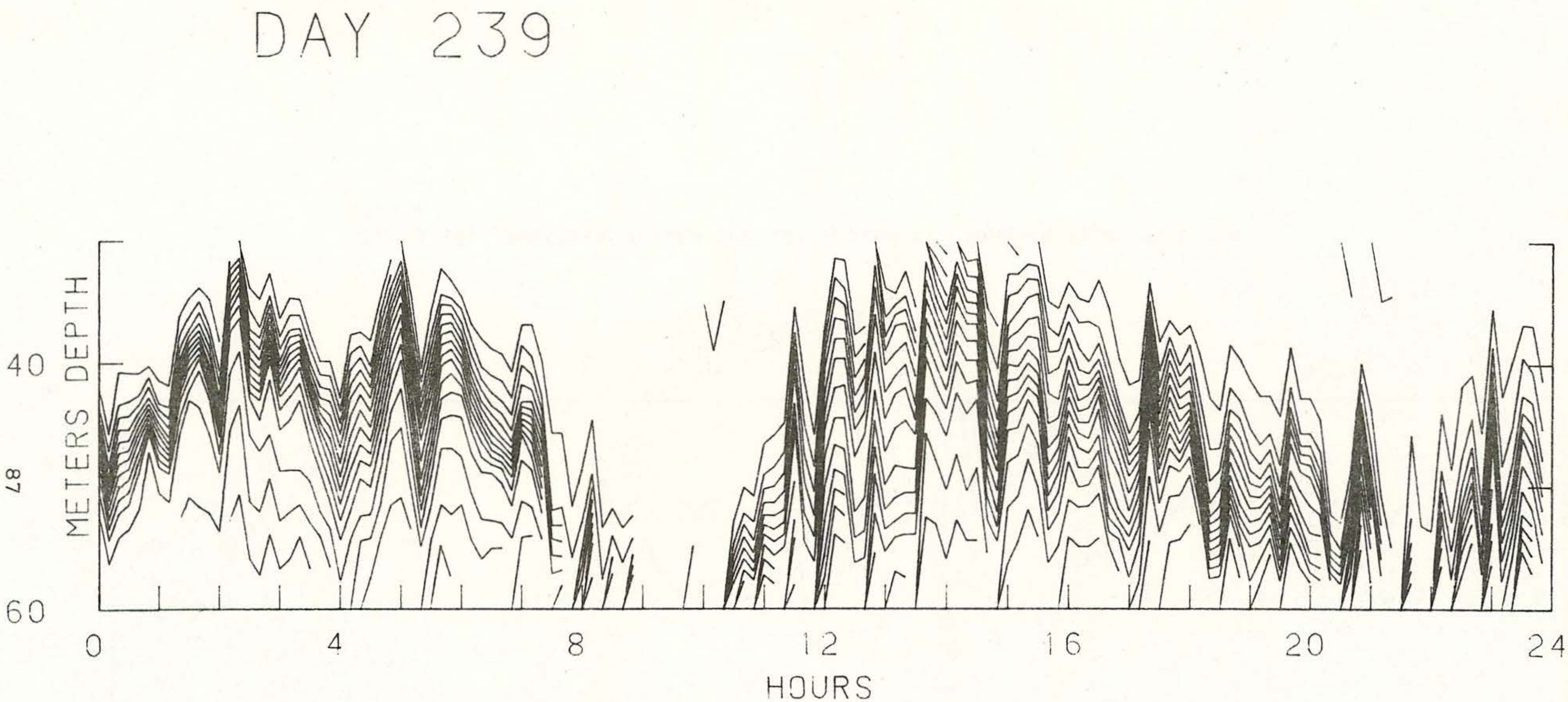


Figure 16. Isotherm depths for .2° increments ranging from 9.2° to 12.2°.

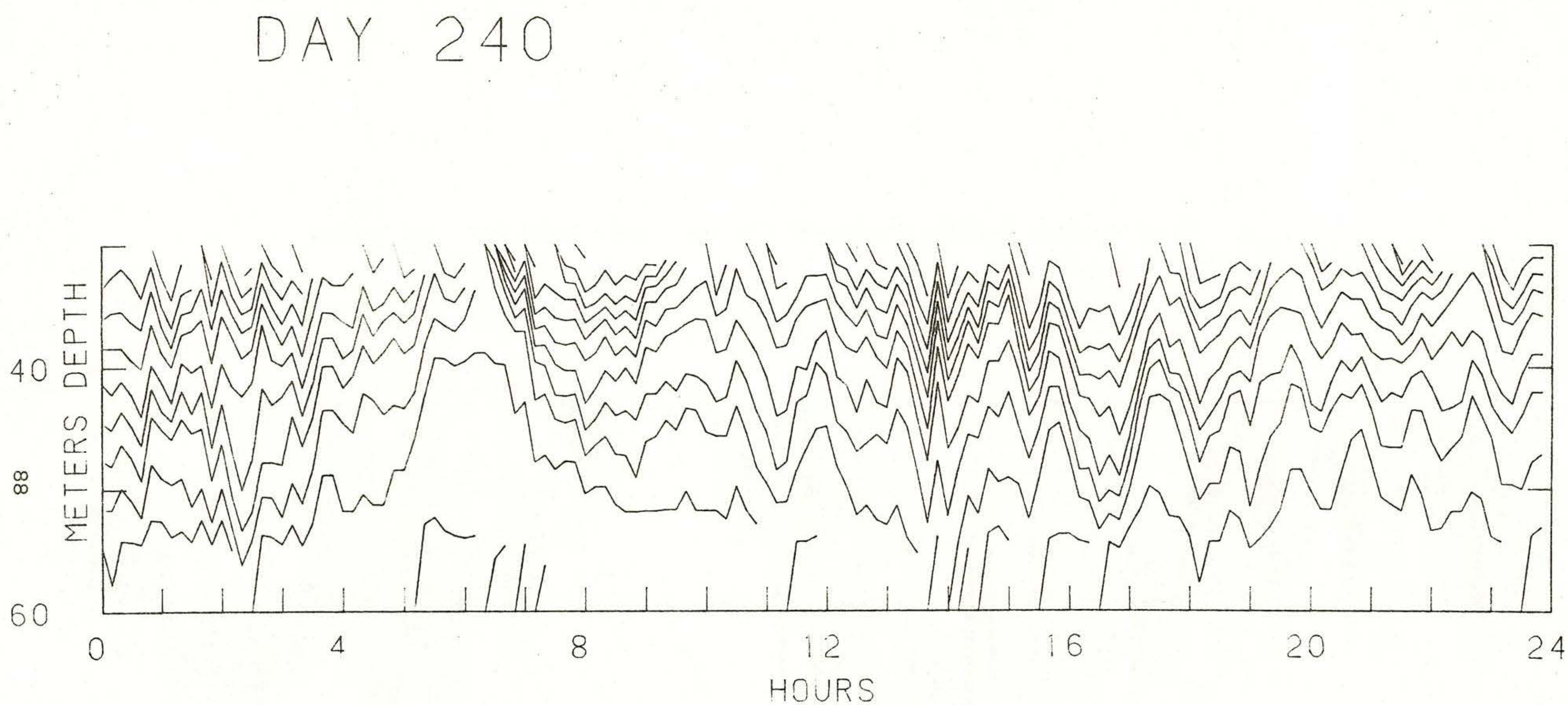


Figure 16. Isotherm depths for .2° increments ranging from 9.4° to 12.6°.

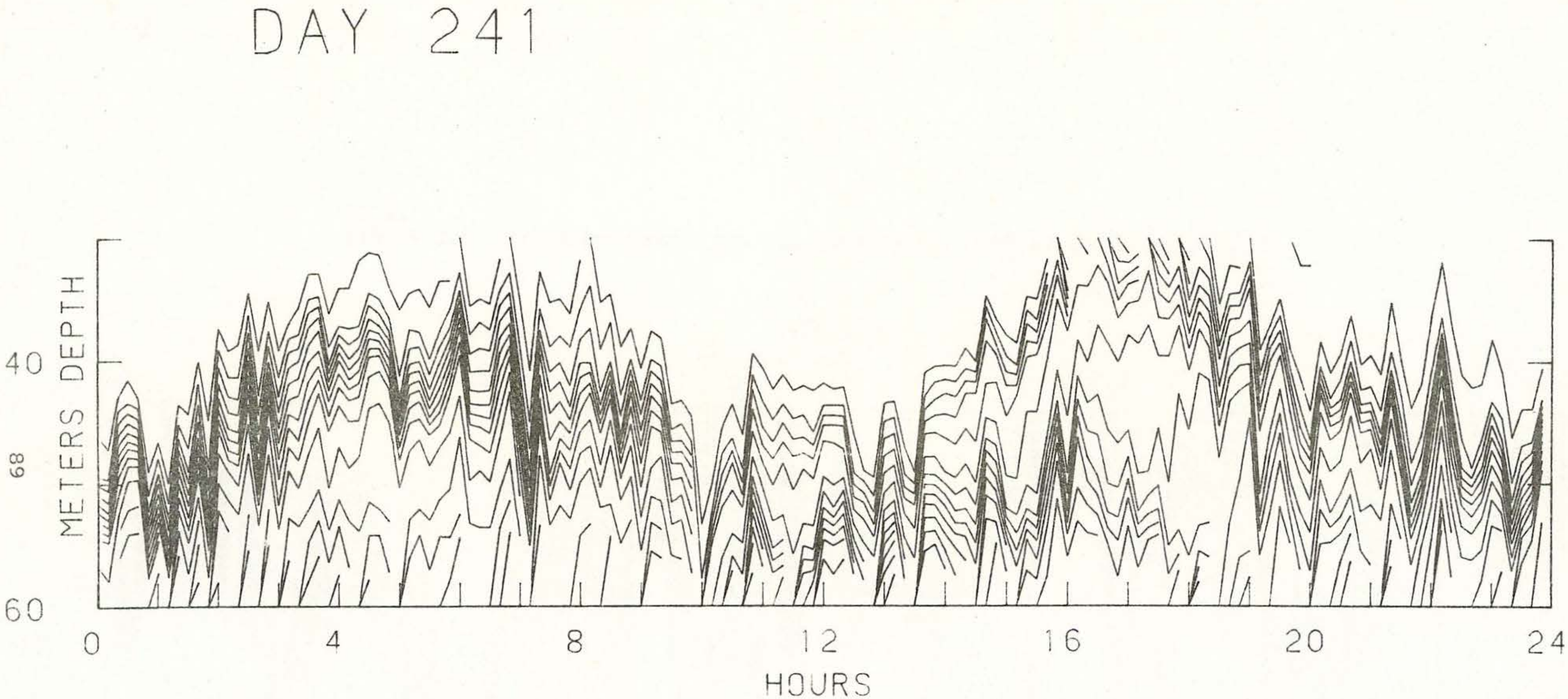


Figure 16. Isotherm depths for .2° increments ranging from 9.8° to 12.2°.

Figure 16. Isotherm depths for .2° increments ranging from 9.2° to 12.6°.

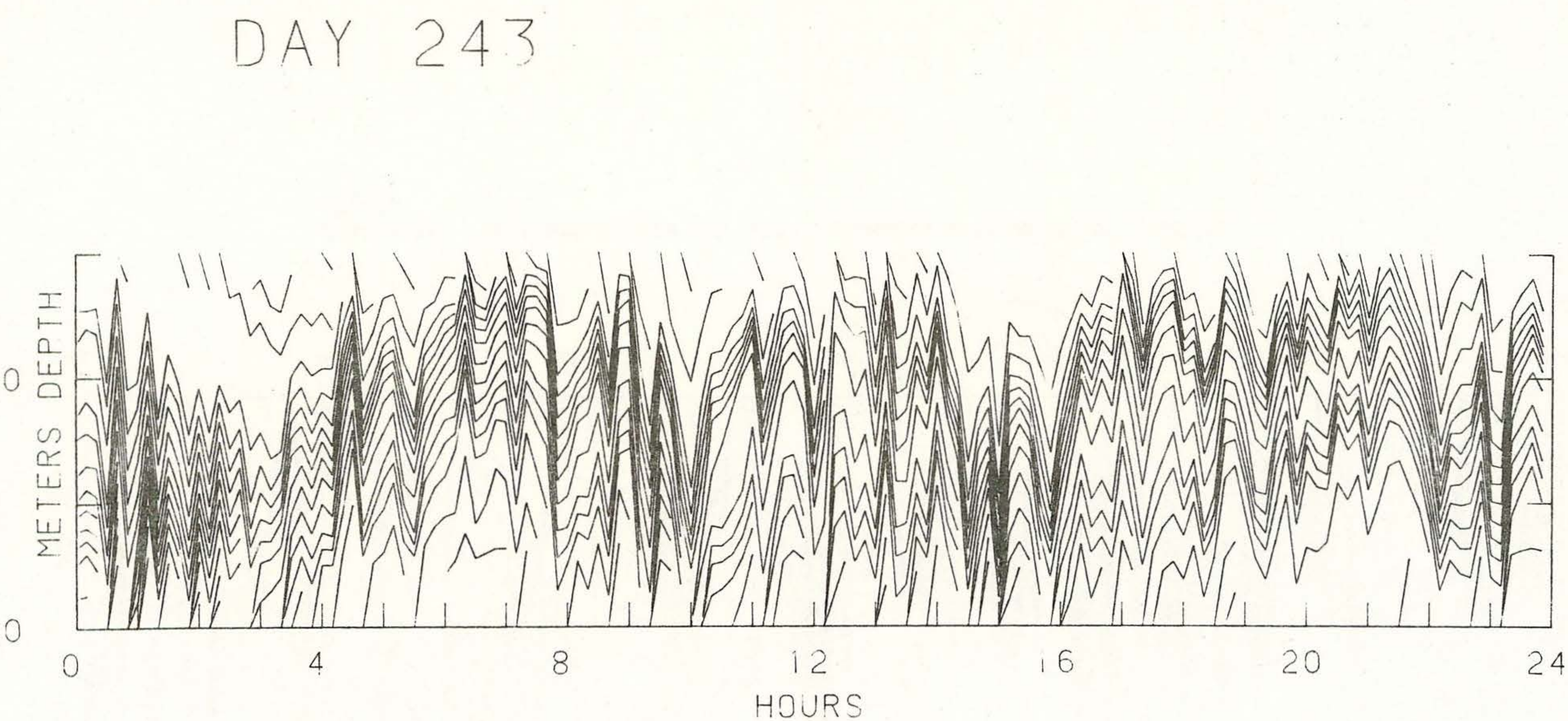


Figure 16. Isotherm depths for .2° increments ranging from 9.6° to 12.4°.

Figure 16. Isotherm depths for .2° increments ranging from 9.8° to 12.4°.

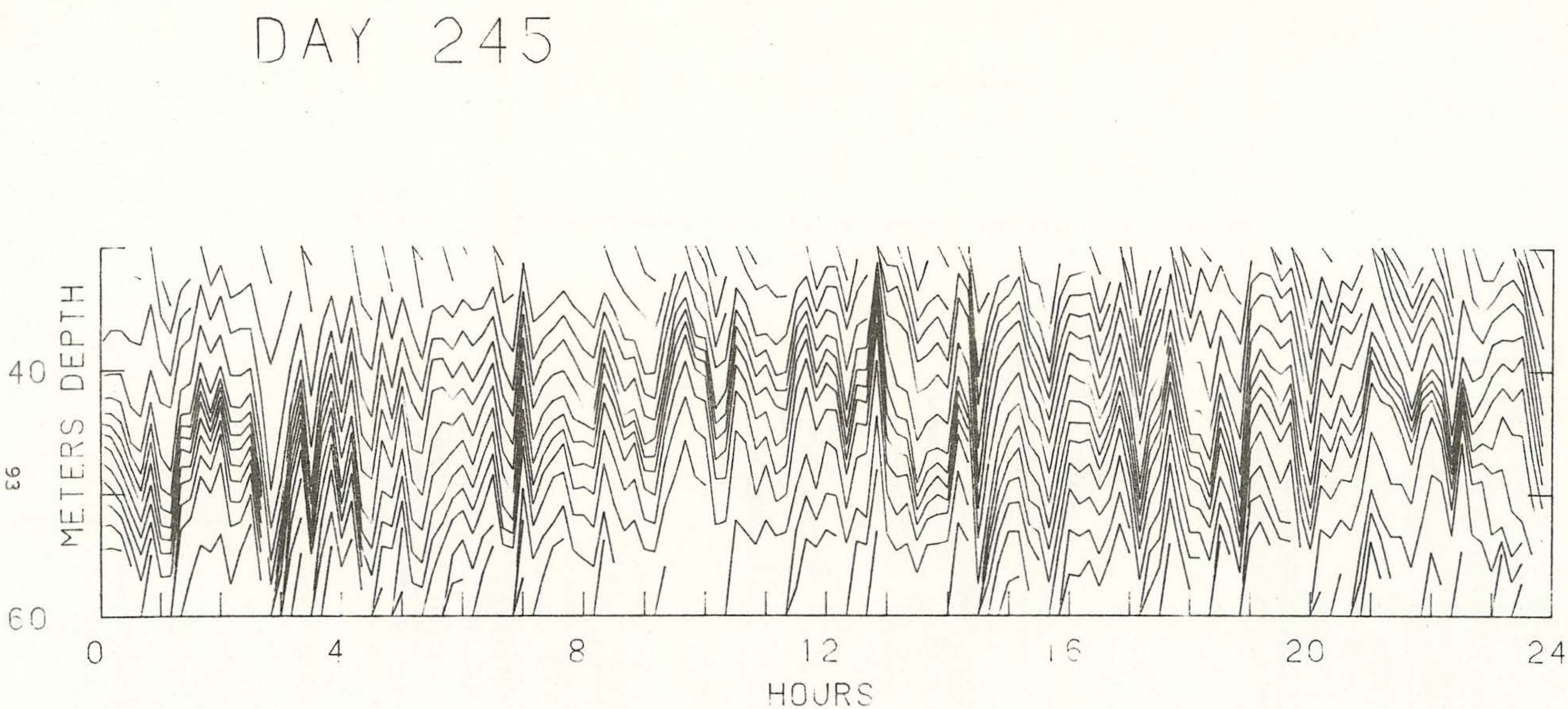


Figure 16. Isotherm depths for .2° increments ranging from 9.6° to 12.4°.

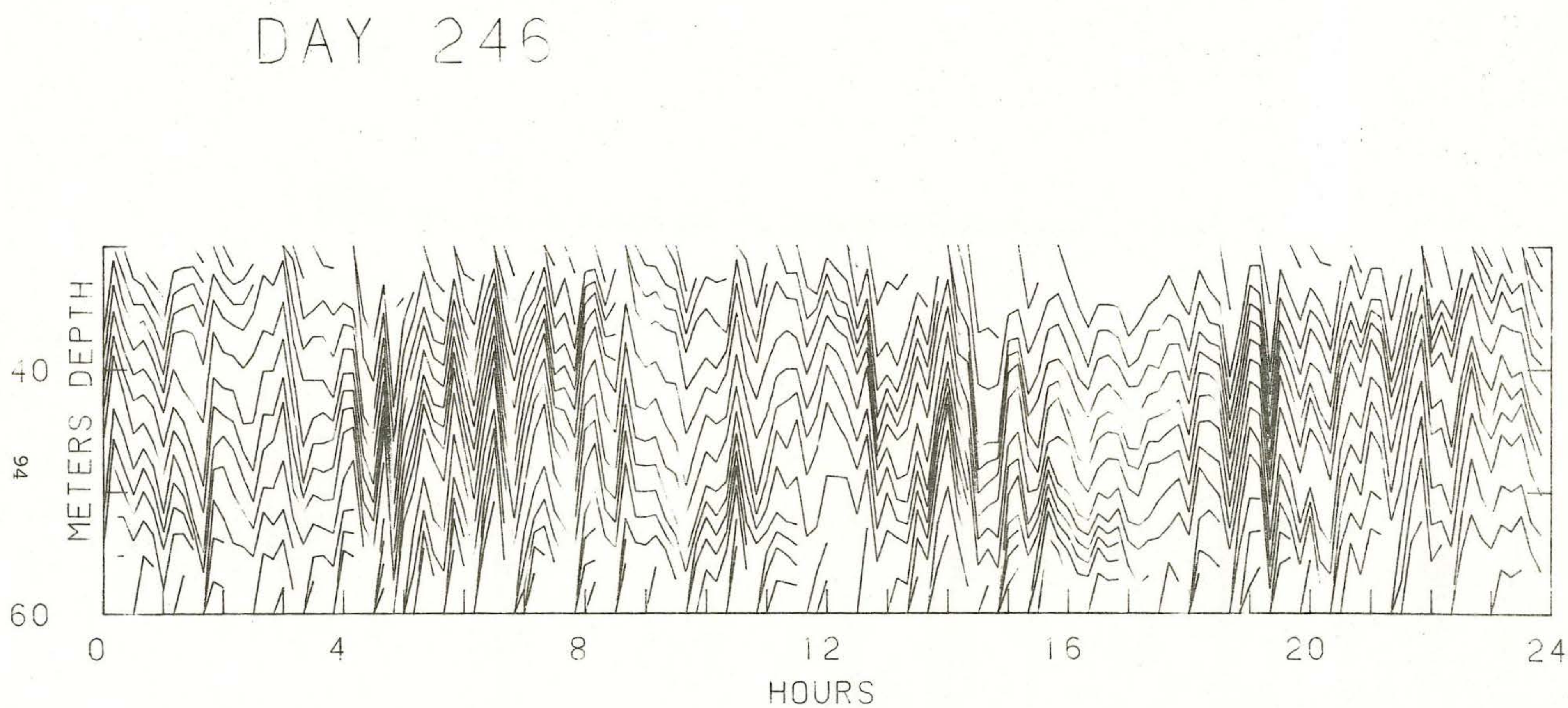


Figure 16. Isotherm depths for .2° increments ranging from 9.6° to 12.4°.

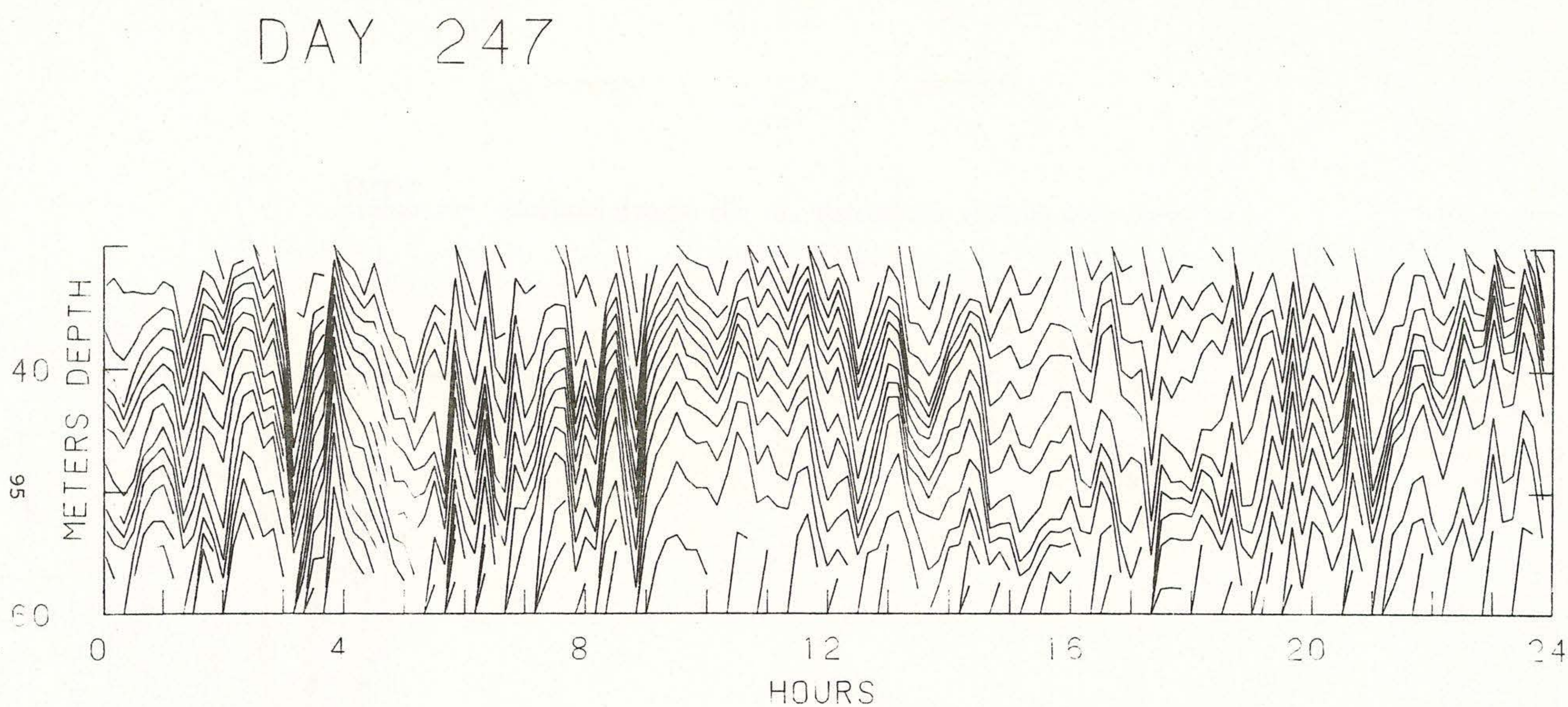


Figure 16. Isotherm depths for .2° increments ranging from 9.6° to 12.4°.

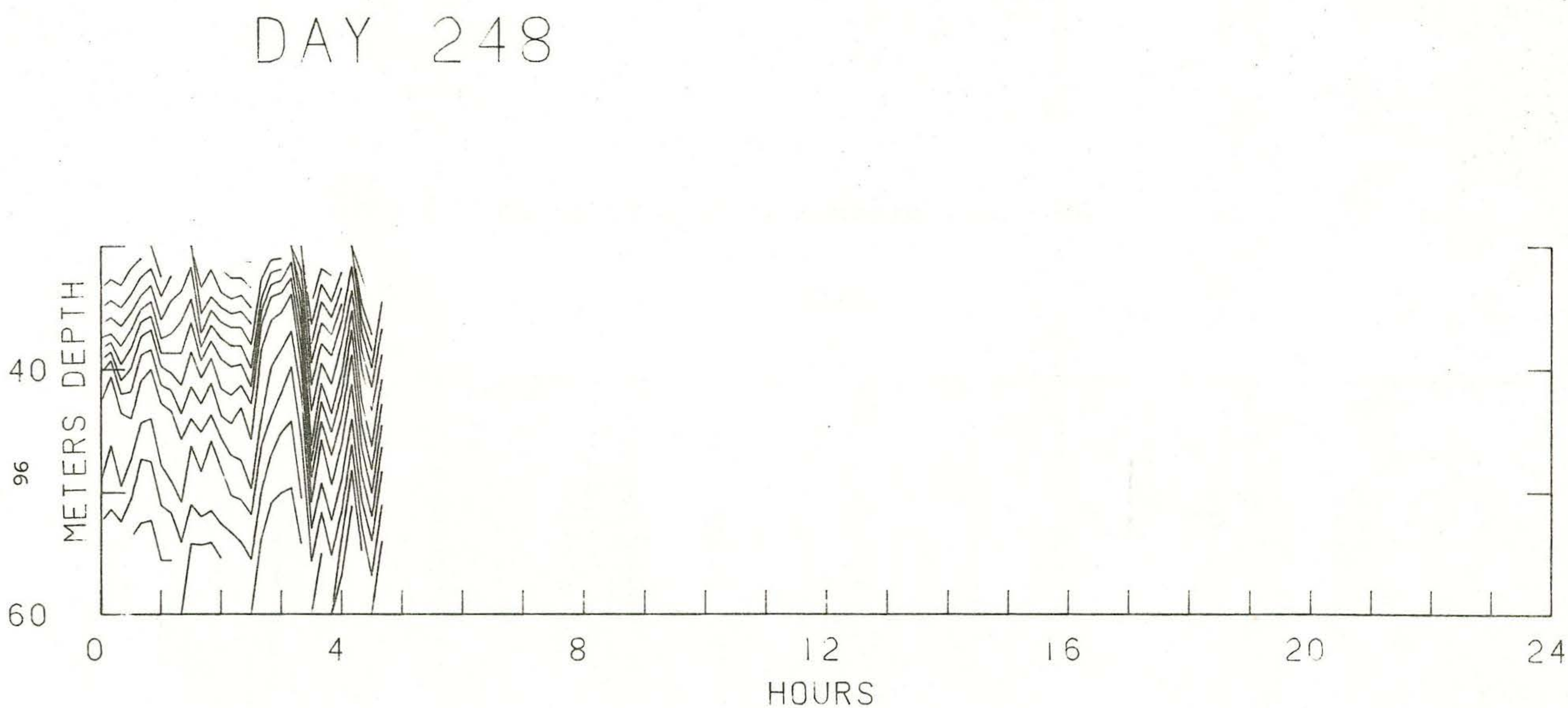


Figure 16. Isotherm depths for .2° increments ranging from 9.8° to 12.4°.

Part III

Expanded Scale XBTs

XBT Data

Some 169 XBTs (expendable bathythermographs) were dropped from ATLANTIS II during the JASIN experiment. Figure 17 shows the area in which the XBTs were dropped. Table 2 lists the time, location, and bucket temperature associated with each drop. Figure 18 shows the patterns of the XBT drop locations.

EXBT System

The standard Sippican Co. Expendable Bathythermograph (XBT) bridge and recording system has an indicated temperature scale of -2°C - 35°C, approximately 5°C/inch and a depth scale of 100 meters/inch. These fixed scales are somewhat awkward when one is working in regions of the ocean where the temperature of the entire water column varies by as little as 2°C. To overcome these limitations we replaced the Sippican XBT bridge and recorder with a simple and inexpensive bridge. We utilized an Hewlett Packard strip chart recorder (model 7100B) to plot the output from the bridge. Figure 19 illustrates the difference between the EXBT scales and the standard Sippican XBT recorder scales.

Theory of Operation

The Sippican XBT probe consists of a molded projectile with a thermistor recessed in the nose, which falls through the water column at an approximately constant rate. The resistance of the thermistor is sensed through a copper wire which unwinds from a spool contained within the projectile (see Fig. 20a) and from a second spool remaining in the launcher.

The thermistor's resistance, R_T, decreases about 5% per degree centigrade temperature increase. In addition to the resistance change of interest, the resistance of the copper wire, R_C, and the sea water to ship's ground, R_{SW}, vary continuously. Figure 20c details the resistance involved in the primary and secondary measurement loops. The secondary loop is identical to the primary loop except that it does not contain a thermistor.

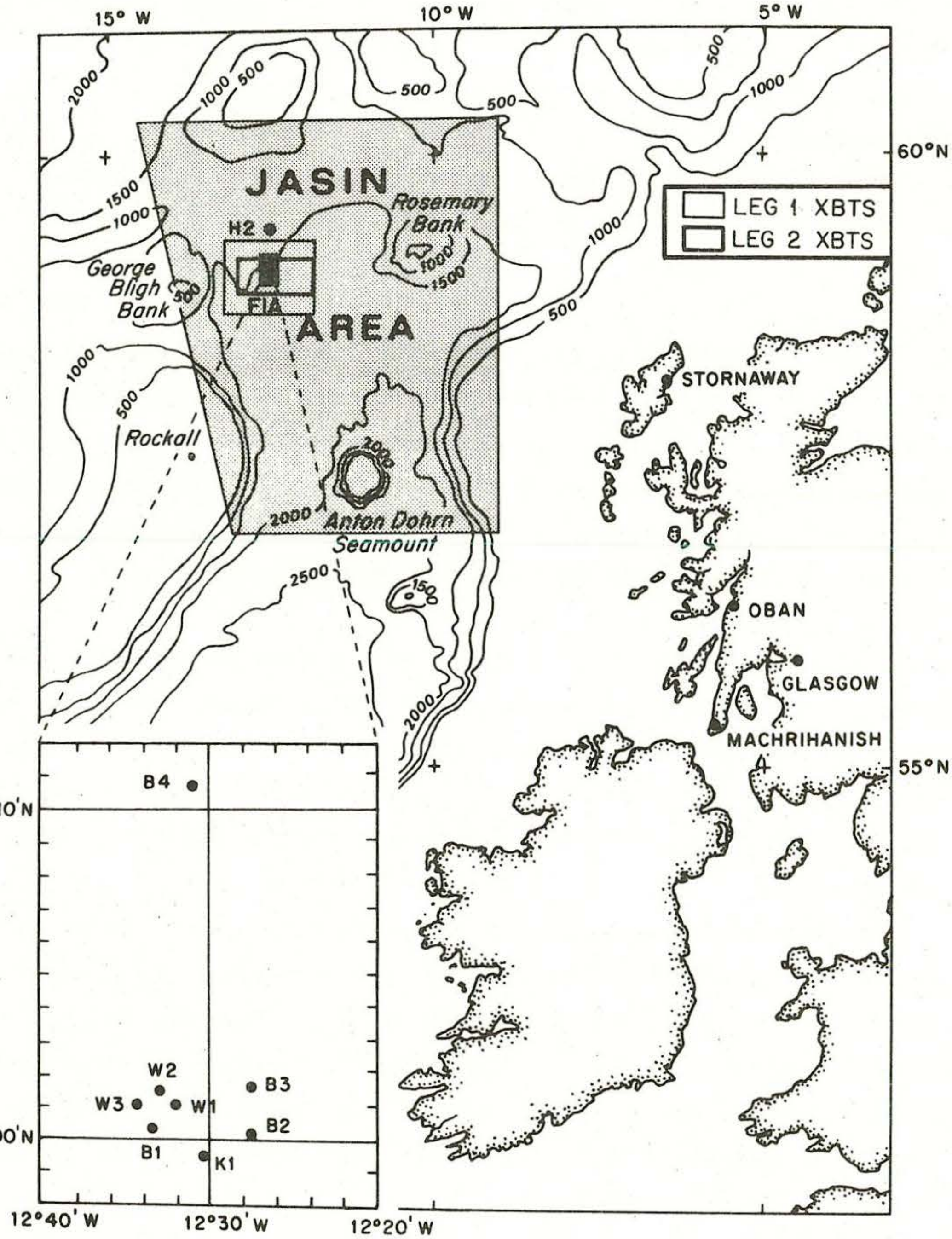


Figure 17. XBT positions.

Table 2

JASIN 1978 ATLANTIS-II-102

XBT Positions

ID #	Date	UTC START TIME	LAT (N)	LONG (W)	COMMENTS
LEG 1					
1	8-7	1300	59° 15.56	13° 00.37	SEA SURFACE TEMP = 13.1°C
2	7	1433	13.64	12° 58.72	13.2
3	7	1534	12.56	55.53	13.4
4	7	1654	10.68	52.58	13.3
5	7	1758	09.81	49.64	13.1
6	7	1903	08.38	47.76	13.5
7	7	1937	07.11	43.86	13.1
8	7	2113	05.26	39.63	13.2
8A	7	2118	04.92	38.32	-
9	7	2137	04.58	38.29	13.2
10	8-8	0131	58° 56.82	24.66	13.5?
10A	8	0136	56.65	24.04	13.5
11	8	-	55.73	22.13	13.3
12	8	0308	54.27	19.36	13.5
13	8	0339	52.90	16.56	13.3
14	8	0507	51.29	13.80	13.7
15	8	0532	49.99	11.03	13.2
16	8	0655	48.06	07.60	13.5
17	8	0747	47.40	05.86	13.2
18	8	1118	45.91	02.37	13.2
19	8	1138	44.47	11° 59.76	13.1
20	8	1250	44.15	12° 00.50	13.3
21	8	1300	45.01	02.03	13.1
22	8	1310	46.07	03.82	13.1
23	ABORTED				
23A	8	1321	47.41	06.07	13.0
24	8	1330	48.50	07.91	13.2
25	8	1340	49.76	09.89	13.1
26	8	1350	51.05	11.68	13.1
27	8	1400	52.40	13.38	13.1
28	8	1410	53.74	15.13	13.2
29	8	1420	55.17	16.40	13.1
30	8	1430	56.80	17.31	13.1
31	8	1440	58.34	18.17	13.1
32	8	1450	59.82	19.39	13.2
33	8-10	0052	59° 00.00	30.00	13.3
34	10	0100	00.23	22.70	13.0
35	10	0110	00.26	20.01	13.0
36	10	0120	00.22	17.31	13.0
37	10	0130	00.27	14.64	13.0
38	10	0140	00.21	11.88	12.95
39	10	0150	00.19	09.12	12.95
40	10	0200	00.23	06.37	12.95

Table 2 (continued)

XBT Positions

ID #	DATE	UTC START TIME	LAT (N)	LONG (W)	COMMENTS
41	8-10	0210	59° 00.19	12° 03.61	SEA SURFACE TEMP = 12.95°C
42	10	0220	00.05	00.86	12.95
43	10	0224	58° 59.98	11° 59.83	12.95
44	10	0230	59.47	59.78	12.95
45	10	0240	58.50	12° 01.68	12.95
46	10	0250	57.52	03.56	12.95
47	10	0300	56.48	05.41	12.95
48	10	0310	55.60	07.36	12.9
49	10	0320	54.55	09.23	12.95
50	10	0331	53.51	11.35	13.0
51	10	0340	52.66	13.09	12.95
52	10	0350	51.69	14.95	12.95
53	10	0400	50.75	16.80	13.0
54	10	0410	49.69	18.86	13.0
55	10	0418	49.03	20.17	13.05
56	10	1200	59° 05.49	25.99	13.5
57	10	1215	05.42	21.58	13.1
58	10	1223	05.32	18.52	-
59	10	1230	05.23	17.01	13.1
60	10	1245	05.12	12.37	13.2
61	10	1300	05.05	07.75	12.9
62	10	1315	05.05	03.21	12.8
63	10	1330	05.11	11° 58.73	12.9
64	10	1345	04.82	54.62	12.9
65	10	1400	02.80	54.76	13.0
66	10	1415	00.41	54.93	13.2
67	10	1430	58° 58.22	54.82	13.2
68	10	1445	56.10	54.76	13.45
69	10	1500	53.96	54.90	13.5
70	10	1515	51.89	54.93	13.4
71	10	1530	49.80	54.88	13.4
72	10	1545	47.74	54.83	13.1
72A	10	1600	45.63	54.98	13.3
73	10	1615	44.67	57.70	13.1
74	10	1630	44.79	12° 02.29	13.0
75	10	1645	44.95	06.88	13.0
76	10	1700	44.97	11.47	13.2
77	10	1715	45.03	16.01	13.2
78	10	1730	45.04	20.66	13.1
79	10	1745	45.05	25.27	13.0
80	10	1800	47.68	25.21	13.0
81	10	1815	50.40	24.89	13.0
82	10	1830	53.08	24.97	13.0
83	10	1845	55.81	25.28	13.1

Table 2 (continued)

XBT Positions

ID #	DATE	UTC START TIME	LAT (N)	LONG (W)	COMMENTS
LEG 2					
84	9-4	0830	58° 56.18	12° 29.96	TEST
85	4	0900	56.38	23.54	START THERMISTOR CHAIN BOX
86	4	0910	16.65	21.60	TURN NORTH
87	4	0920	57.64	21.47	
88	4	0930	58.60	21.42	
89	4	0940	59.60	21.32	
90	4	0950	00.61	21.20	
91	4	1000	59° 01.59	21.08	
92	4	1010	02.62	20.97	
93	4	1020	03.61	20.89	
94	4	1030	04.21	21.68	TURN WEST
95	4	1040	00.21	23.45	
96	-				
97	4	1050	04.13	25.26	
98	4	1100	04.02	27.03	
99	4	1110	03.95	28.79	
100	4	~1120	03.91	30.55	
101	4	1123	03.91	31.44	
102	4	1130	03.78	32.35	
103	4	1140	03.77	34.16	
104	4	1150	03.63	36.01	
105	4	1200	03.59	37.82	TURN SOUTH
106	-				
107	4	1210	02.73	38.28	
108	4	1220	01.61	38.23	
109	4	1230	00.48	38.17	
110	4	1240	58° 59.40	38.19	
111	4	1250	58.28	38.21	
112	4	1300	57.19	38.24	
113	4	1310	56.18	38.29	
114	4	1320	55.79	39.65	TURN EAST
115	4	1330	55.90	34.99	
116	4	1340	55.92	33.11	
117	4	1350	55.95	31.23	
118	4	1400	55.97	29.41	
119	4	1410	56.00	27.55	
120	4	1420	56.05	25.77	
121	4	1430	56.13	23.97	
122	4	1440	56.13	22.17	
122A	4	1450	56.97	21.94	TURN NORTH

Table 2 (continued)

XBT Positions

ID #	DATE	UTC START TIME	LAT (N)	LONG (W)	COMMENTS
123	9-4	1500	58° 57.91	12° 22.07	
124	4	1510	58.90	22.22	
125	4	1520	59.87	22.38	
126	4	1530	59° 00.78	22.54	
127	4	1540	01.70	22.73	
128	4	1550	02.64	22.92	
129	4	1600	03.57	23.13	
130	4	1610	04.26	23.93	TURN WEST
131	4	1620	04.19	25.95	
132	4	1630	04.16	28.02	
133	4	1640	-	-	
134	4	1650	04.07	32.19	
135	4	1700	04.02	34.40	
136	4	1710	04.00	36.67	
137	4	1720	03.86	38.67	
138	4	1734	-	-	
139	4	1740	02.10	39.39	
140	4	1750	01.18	39.67	
141	4	1800	00.33	39.94	
142	4	1810	58° 59.51	40.12	
143	4	1820	58.55	40.25	
144	4	1830	57.61	40.32	
145	9-5	1030	59° 05.31	39.92	
146	5	1045	04.96	38.30	
147	5	1100	05.09	36.22	
148	5	1115	05.23	33.72	
149	5	1130	05.27	31.25	
150	5	1145	05.24	28.66	
150A	5	1150	01.25	27.83	
151	5	1200	05.25	26.20	
152	5	1215	05.33	23.67	
153	5	1230	05.25	21.42	
154	5	1245	04.74	19.68	
155	5	1300	03.38	20.01	
156	5	1315	01.94	20.06	
157	5	1330	00.57	20.01	
158	5	1345	58° 59.15	20.13	
159	5	1400	57.76	19.98	
160	5	1415	56.40	20.12	
161	5	1430	55.11	19.98	
162	5	1445	54.73	22.42	
162A	5	1447	-	-	
163	5	1500	54.75	25.23	
164	5	1515	54.77	28.02	
165	5	1530	54.89	30.63	
166	5	1545	54.86	33.15	
167	5	1600	54.95	35.66	
168	5	1615	54.90	38.07	
169	5	1630	54.07	44.26	

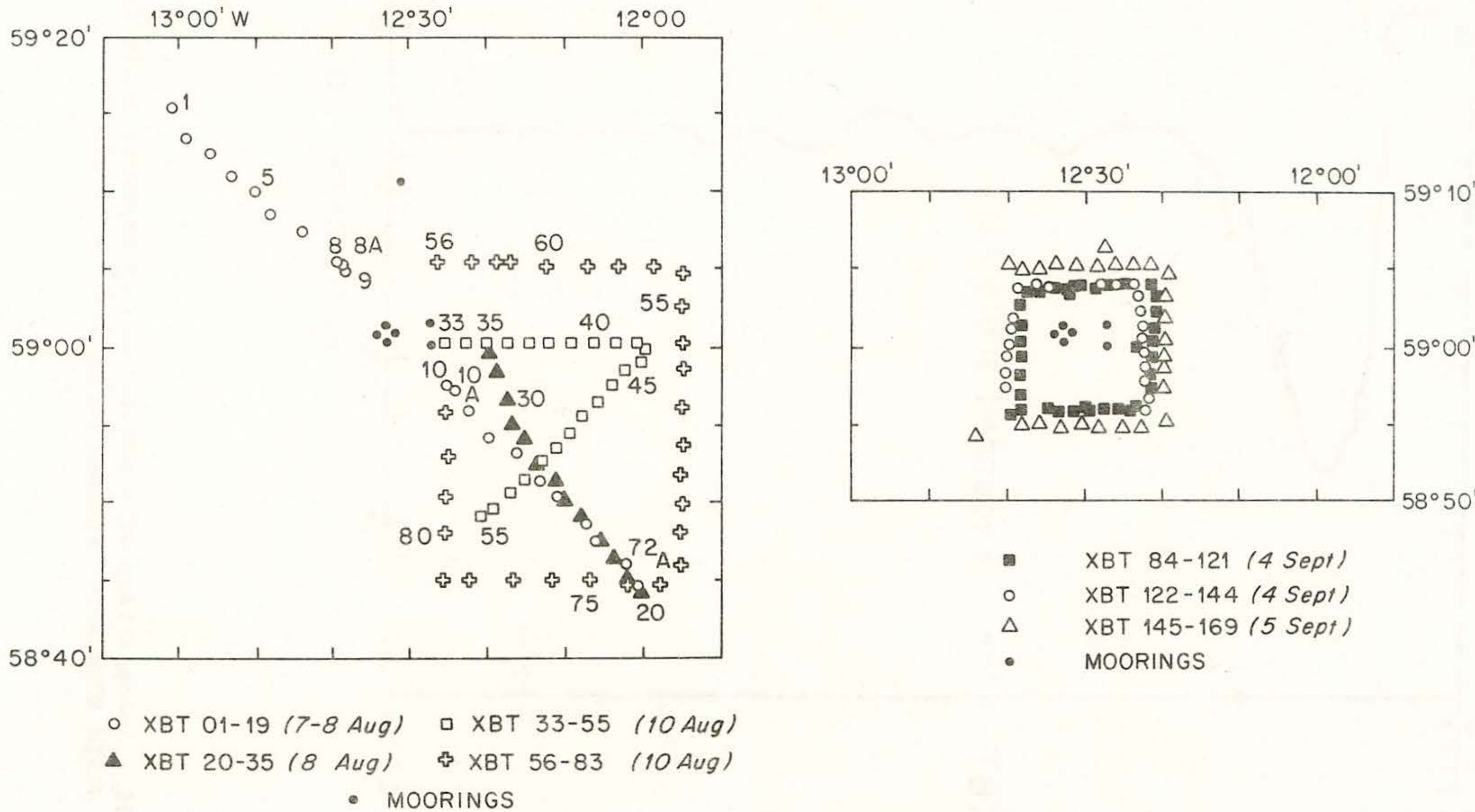


Figure 18. XBT sections during Leg 1 and 2.

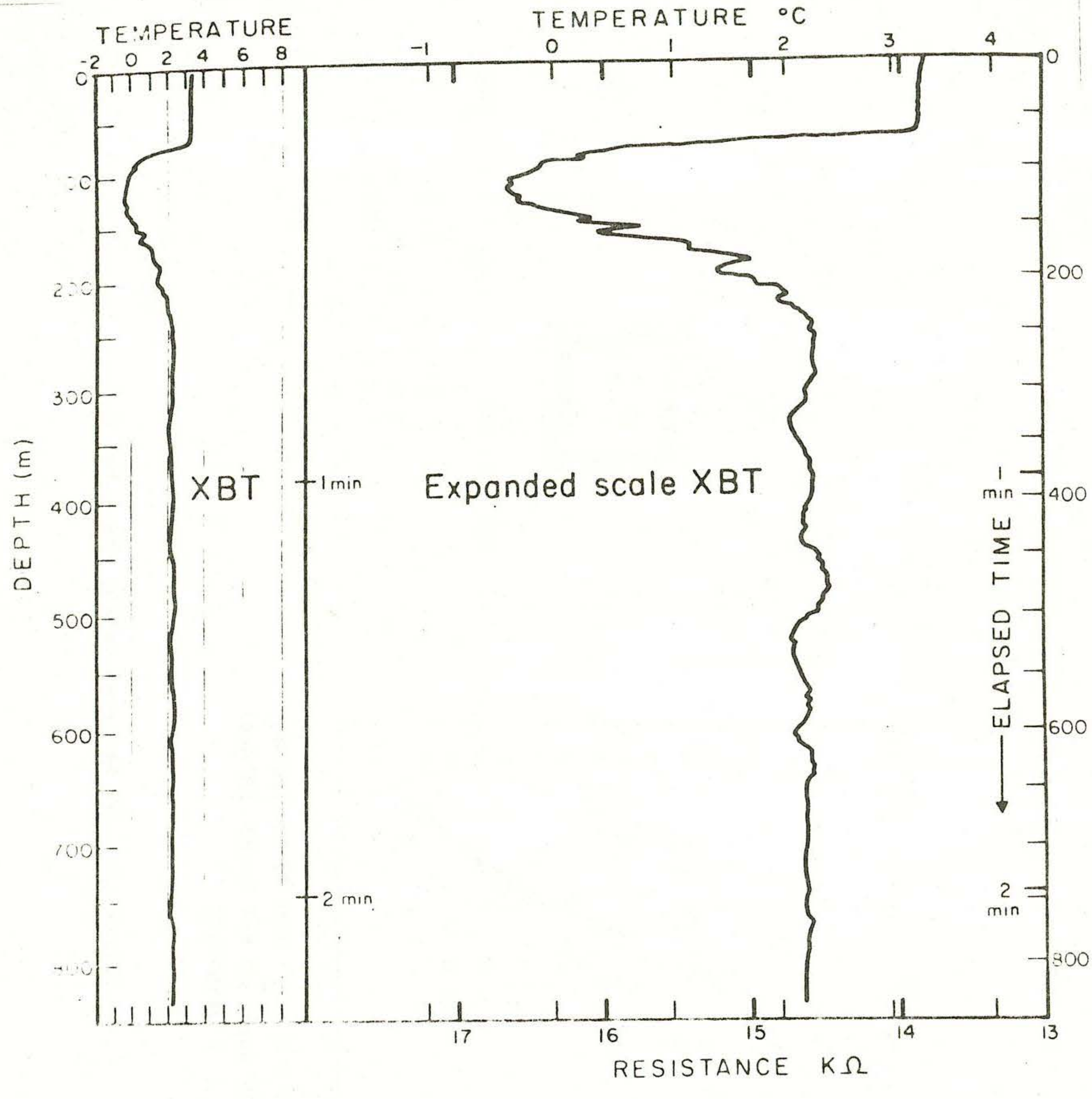


Figure 19. A comparison of a regular and an expanded scale XBT profile. All the JASIN XBTs were recorded on an expanded scale.

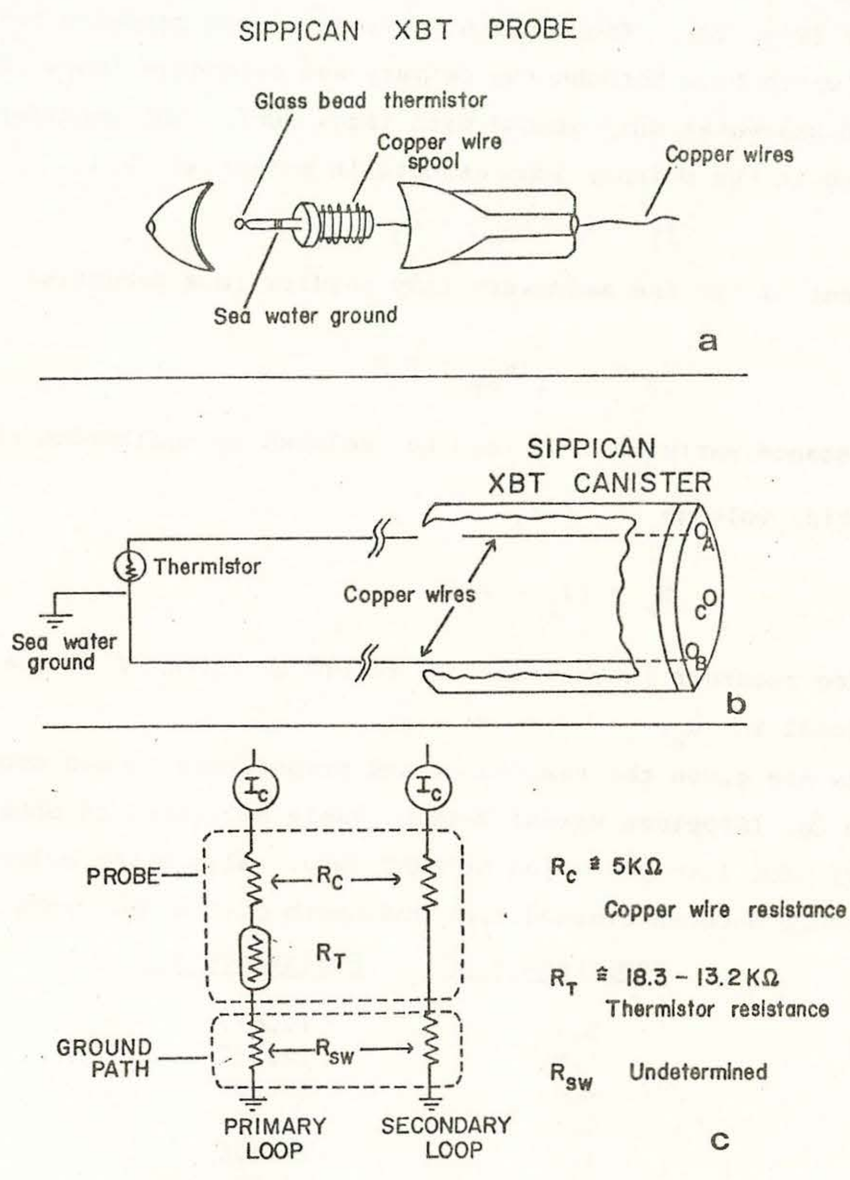


Figure 20. Details of a regular XBT system: probe (a), canister (b), and resistances network (c).

The expanded scale XBT recording system is comprised of the new bridge and analog recorder (Fig. 21). The bridge consists of a precision voltage source, a dual constant current source, and a differential amplifier (Fig. 22). The constant current source supplies two identical currents which flow through the primary and secondary loops of the XBT probe and sea-water-ship ground path (Fig. 20c). The constant current I flowing in the primary loop results in potential V_1:

$$V_1 = I \quad (R_{sw} + R_c + R_t)$$

The current I in the secondary loop results in a potential V_2:

$$V_2 = I \quad (R_{sw} + R_c) \ .$$

The resistance variation R_t can be isolated by monitoring the differential voltage $V_1 - V_2$.

$$R_t = (V_1 - V_2)/I \ .$$

The analog recorder is then used to record an output from the bridge proportional to R_t.

Below are given the resistance and temperature values supplied by Sippican Co. (Sippican Manual R-467B, Table 5-1) used to obtain R(T) and T(R) for interpretation of EXBT data. Also given below is the relationship between elapsed time and depth of the XBT probe.

Temperature °C	Resistance k
5.0	12.697
5.6	12.357
6.0	12.085
6.7	11.699
7.0	11.506
7.8	11.080
8.0	10.958
8.9	10.496
9.0	10.439
10.0	9.948
11.0	9.483
11.1	9.434
12.0	9.043
12.2	8.950
13.0	8.625
14.0	8.230

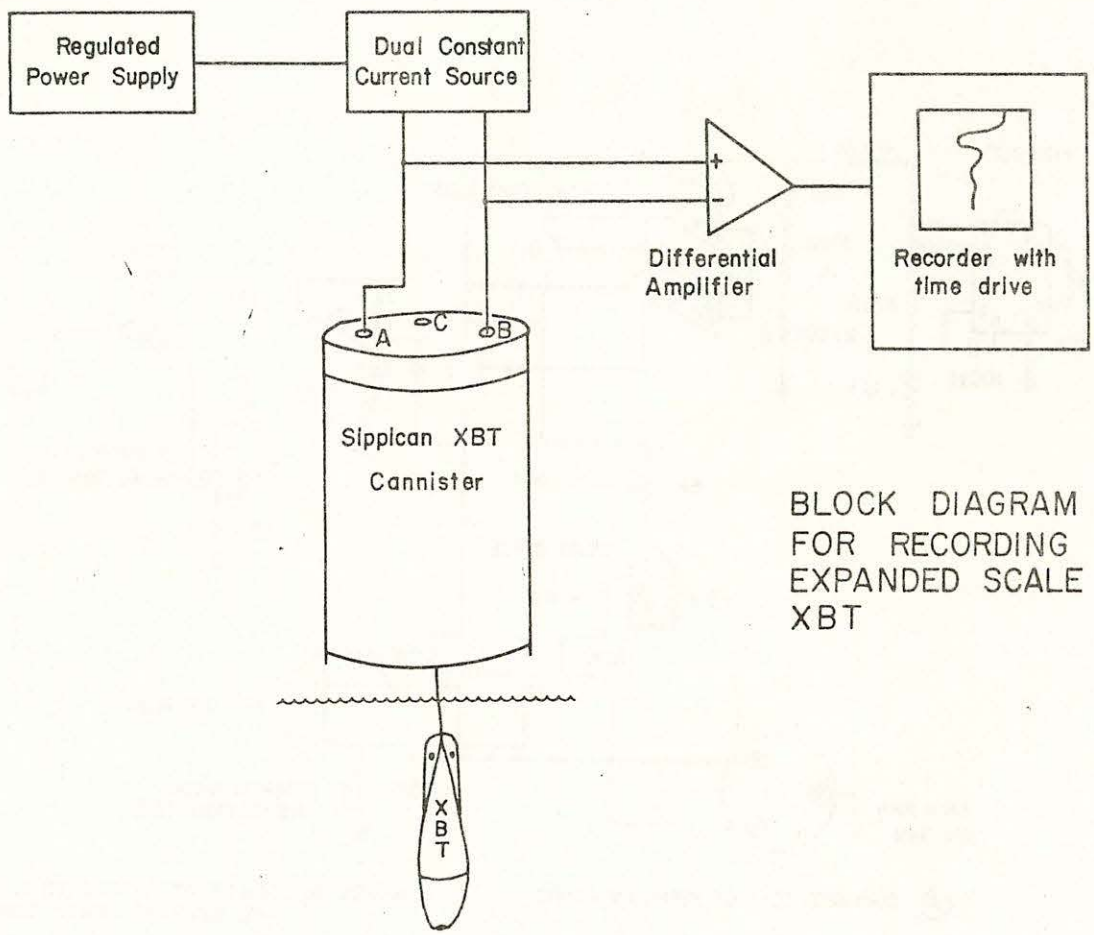


Figure 21. Block diagram of the EXBT system. For details see Figure 22.

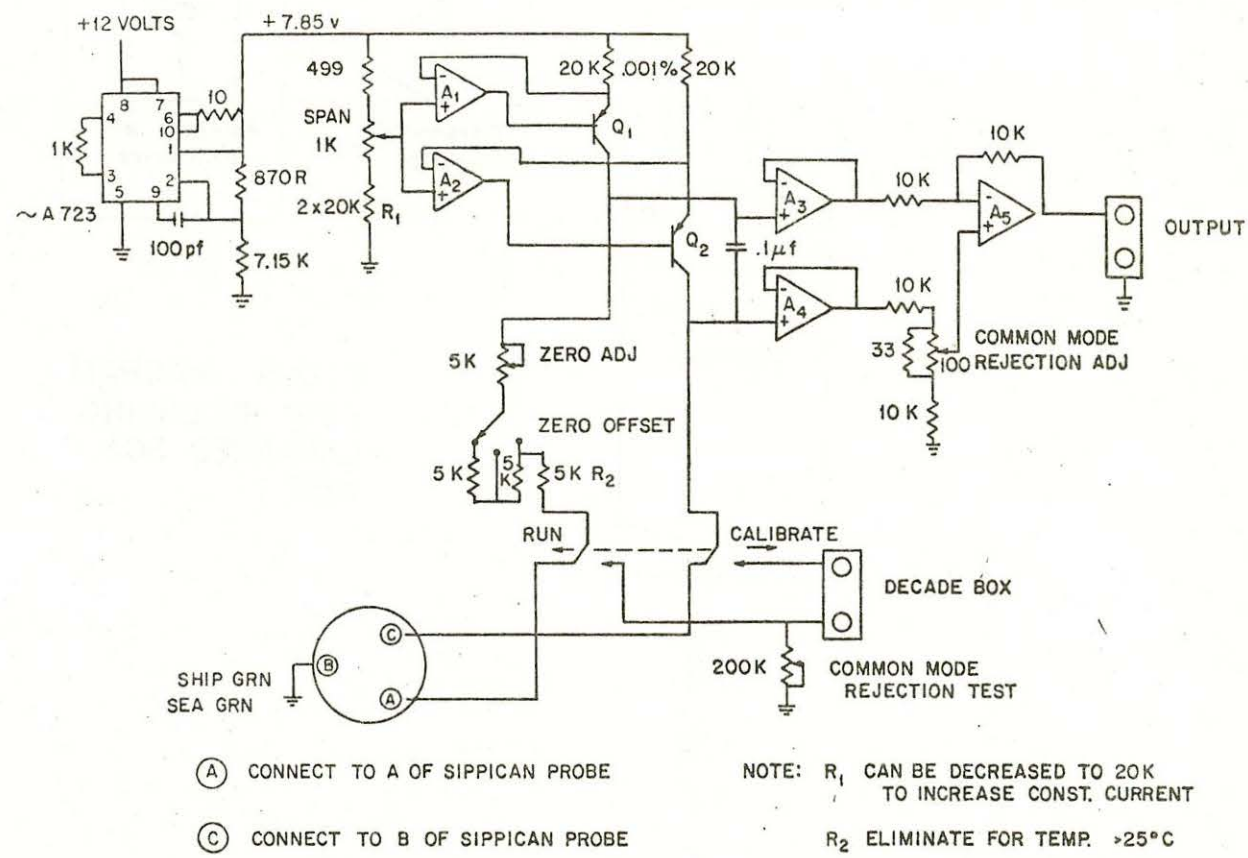


Figure 22. Electric circuit diagram of the EXBT system.

Least-square minimization was used to obtain fourth order polynomials for R(T) and T(R).

$A_0 = 16.32902$		$B_0 = 51.08125$	
$A_1 = -.8336822$		$B_1 = -7.256200$	
$A_2 = .2395431$	10^{-1}	$B_2 = .4455120$	
$A_3 = -.524036$	10^{-3}	$B_3 = -.153488$	10^{-1}
$A_4 = .844554$	10^{-5}	$B_4 = .217192$	10^{-3}

$$T(R) = B_0 + B_1R + B_2R^2 + B_3R^3 + B_4R^4$$

$$R(T) = A_1 + A_1T + A_2T^2 + A_3T^3 + A_4T^4$$

$$*D(t) = 6.472t - 0.00216\ t^2$$

T = Temperature [°C]

R = Resistance [k]

D = Depth [m]

t = Time [secs]

* From Sippican (1970) Ocean Engineering Bulletin No. 1.

Data

The individual traces of XBT data have been grouped in sections and are presented in Figure 26. The depths of the 12.5°, 12°, 11°, 10° and 9°C isotherms are indicated. Figures 23 and 24 are included to show the variation in the T-S relation encountered in the JASIN area. Colder, fresher water was found to the north and warmer, saltier water to the south (Figure 25).

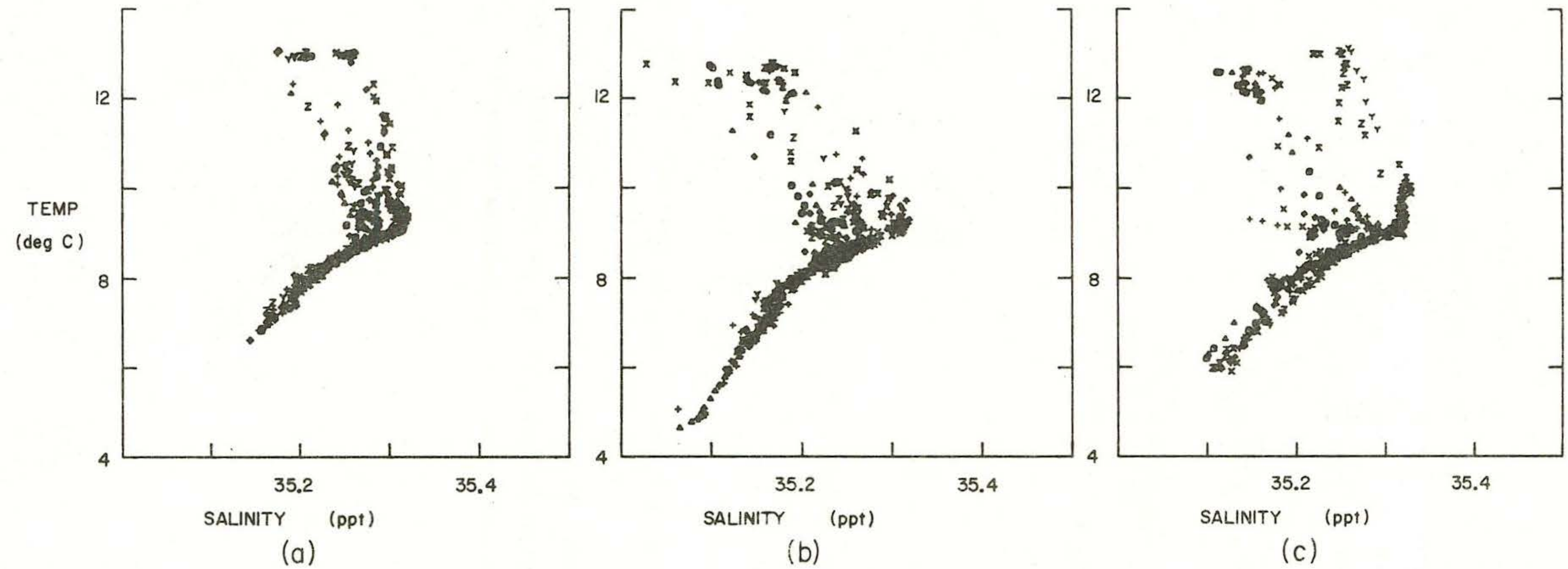


	Fig a STATION	Fig b STATION	Fig c STATION
●	20	73	72
▲	19	62	71
+	18	60	70
✕	[illegible]	92	68
◆	[illegible]	67	67
✦	[illegible]	80	85
✕	[illegible]	76	83
Z	[illegible]	79	82
Y	[illegible]	78	81
✕	24	77	

Figure 23. Temperature - Salinity Plots:
(a) Leg 1, Northwest-Southeast Section;
(b) Leg 2, West-East Section;
(c) Leg 2, North-South Section
(from the JASIN CTD data report, WHOI No. 79-42).

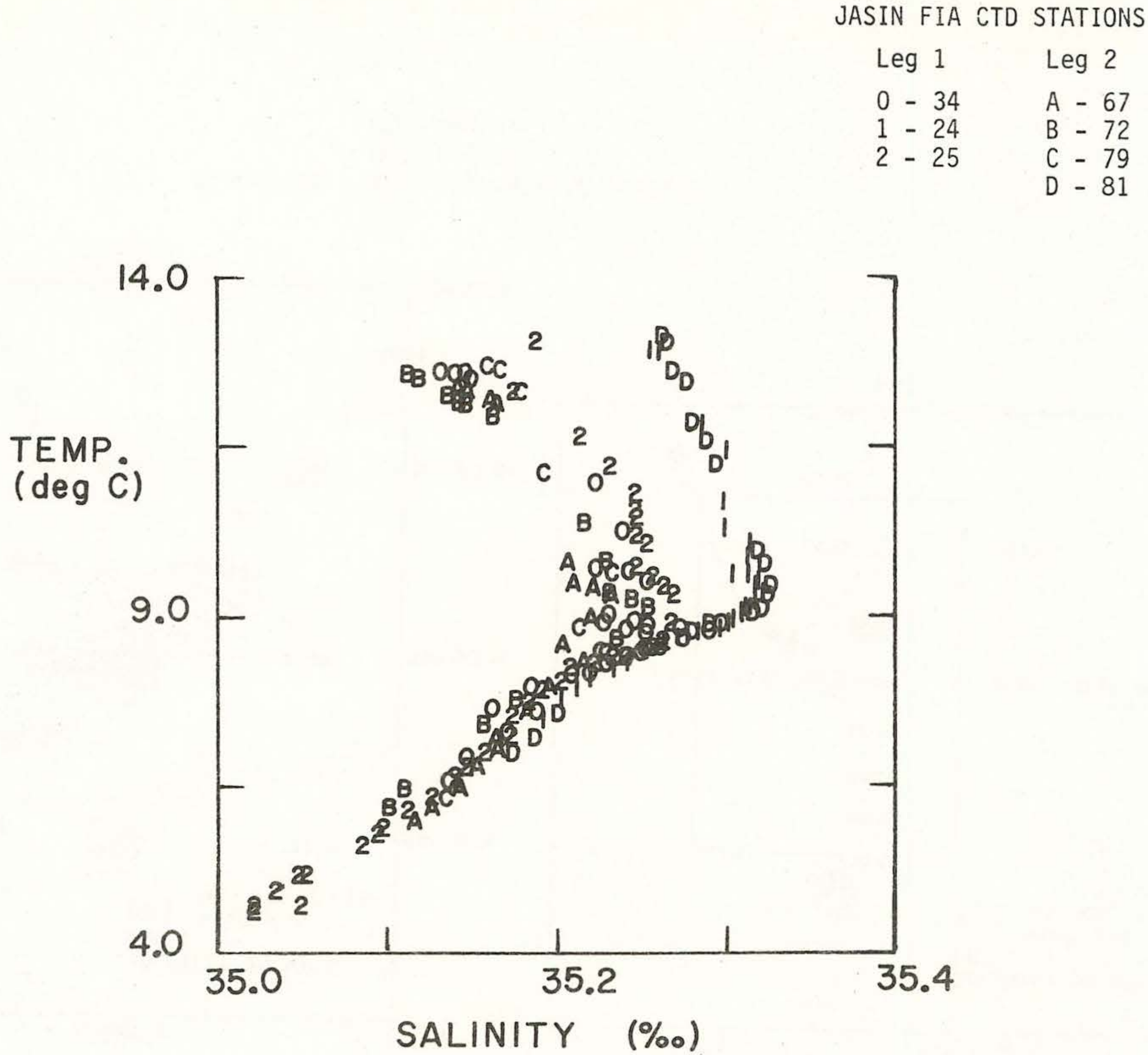


Figure 24. T-S Diagram of FIA CTD Stations.

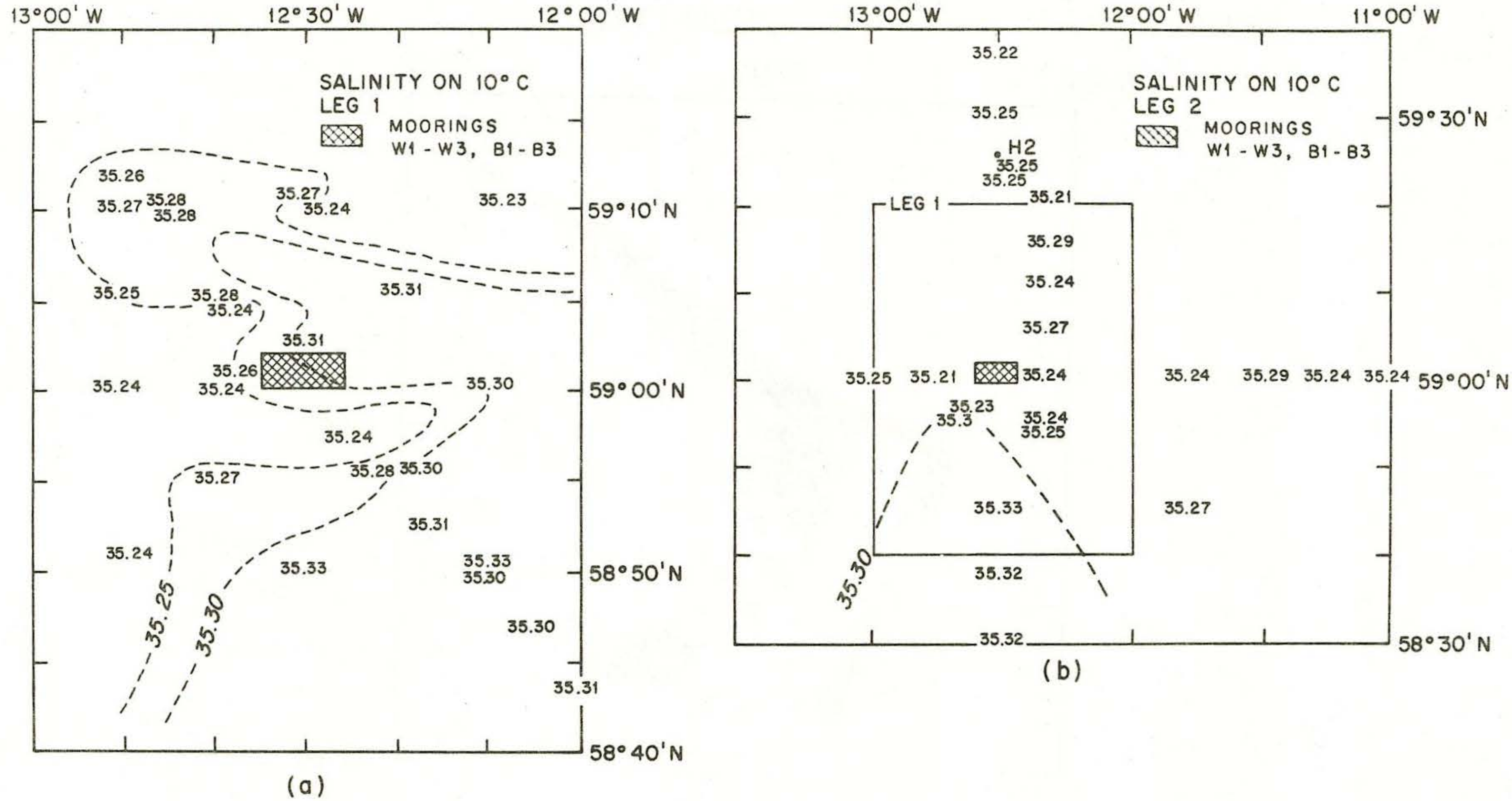


Figure 25. Salinity on 10°C Surface:
(a) Leg 1;
(b) Leg 2.

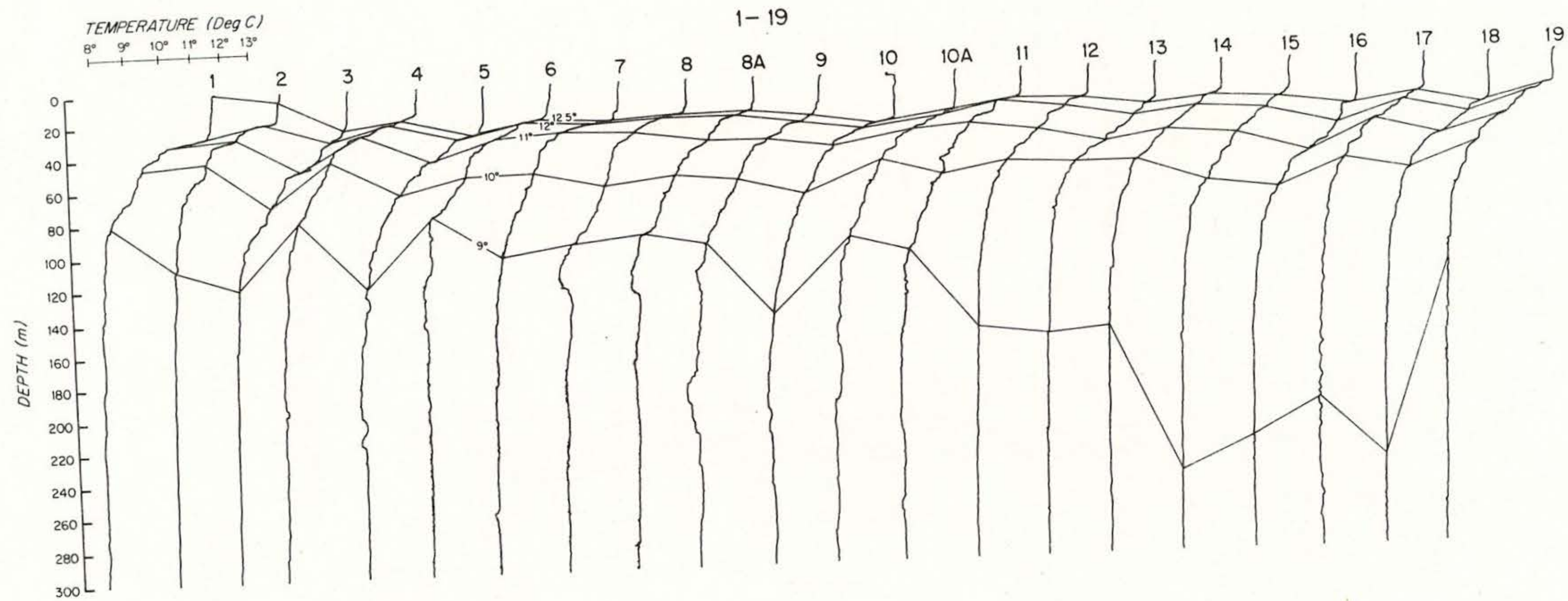
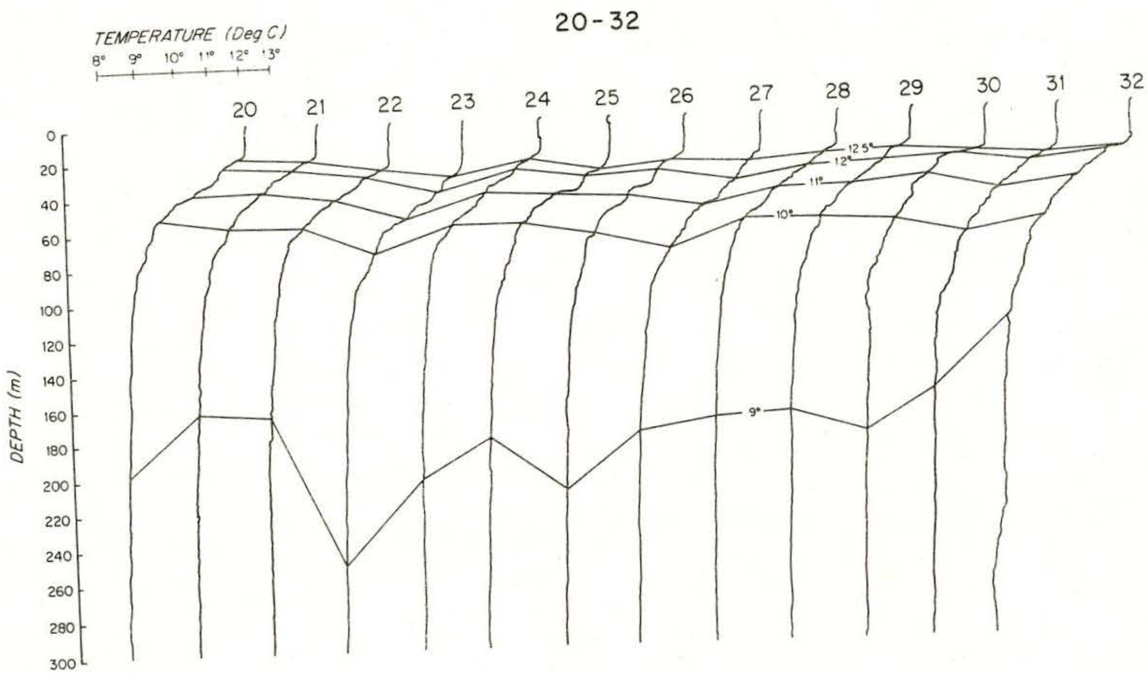
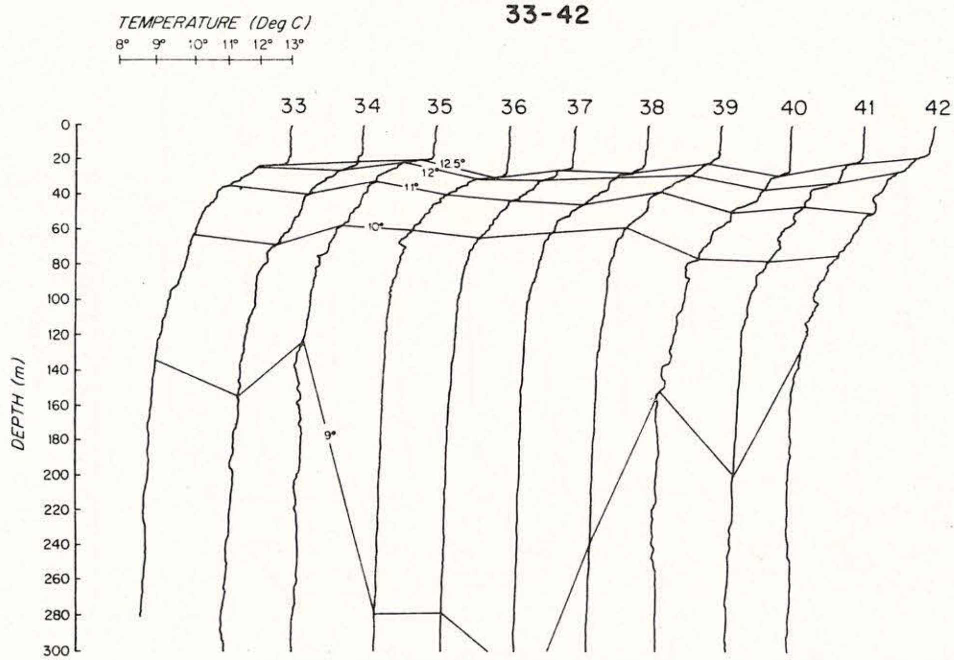


Figure 26. XBT Section 1.

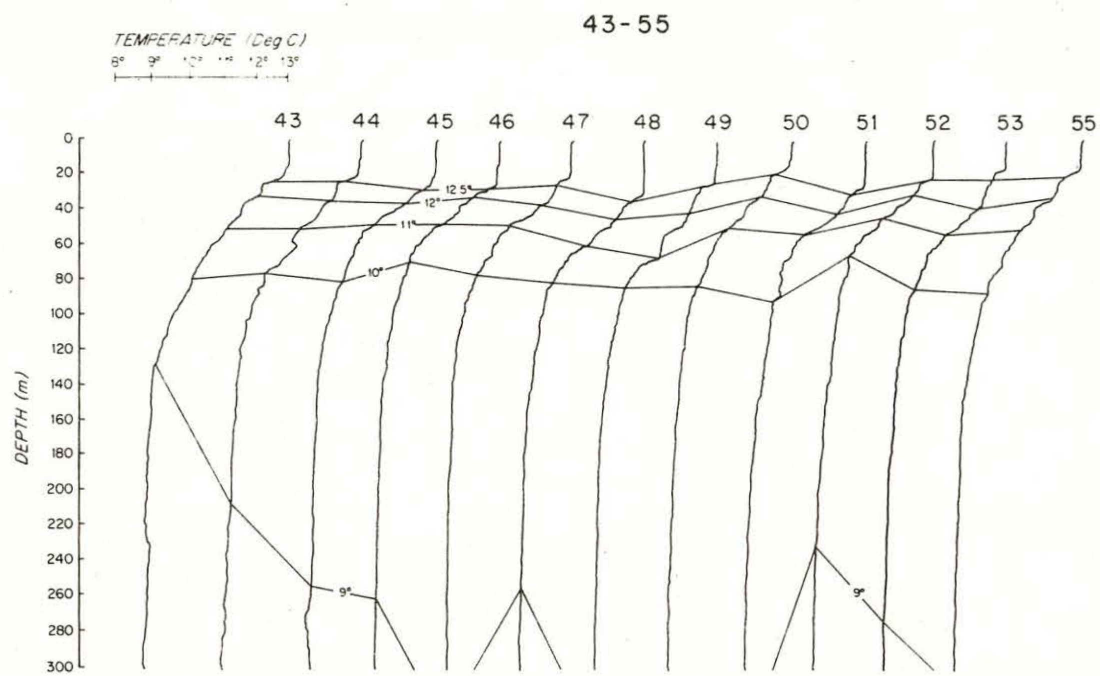


XBT Section 2.

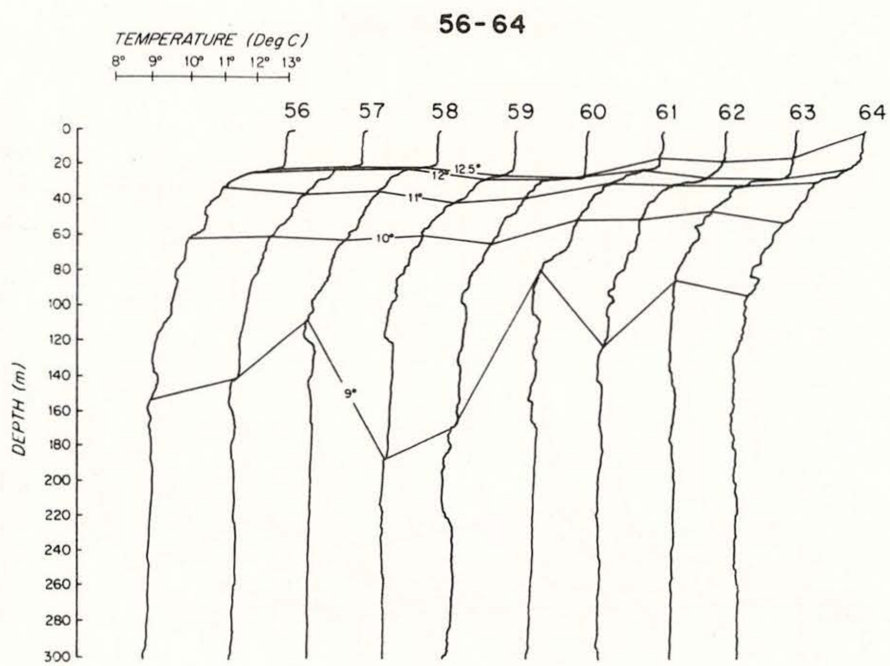
33-42



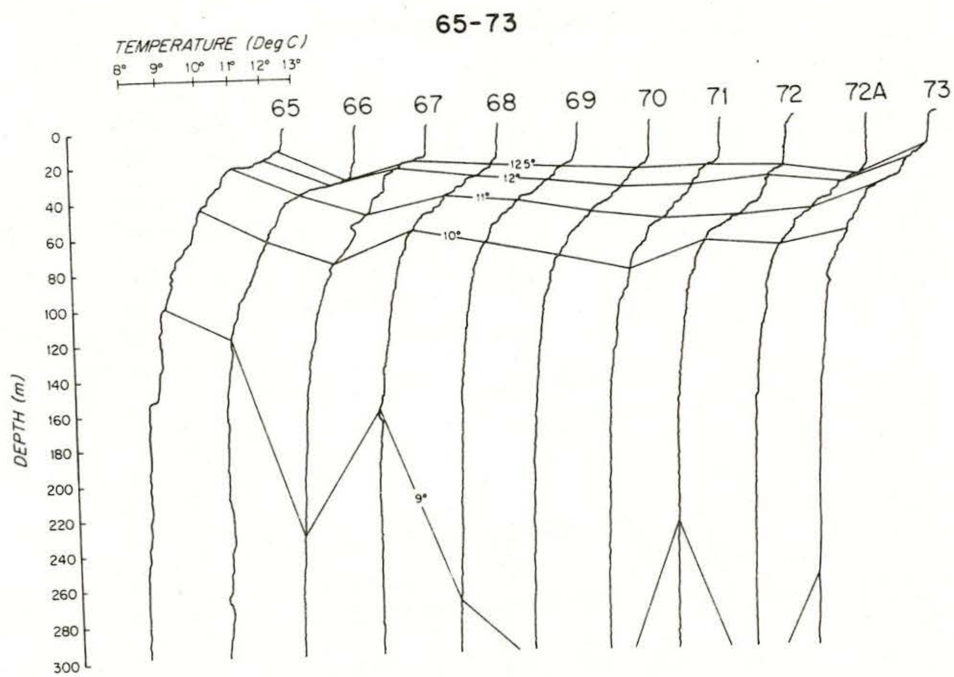
XBT Section 3.



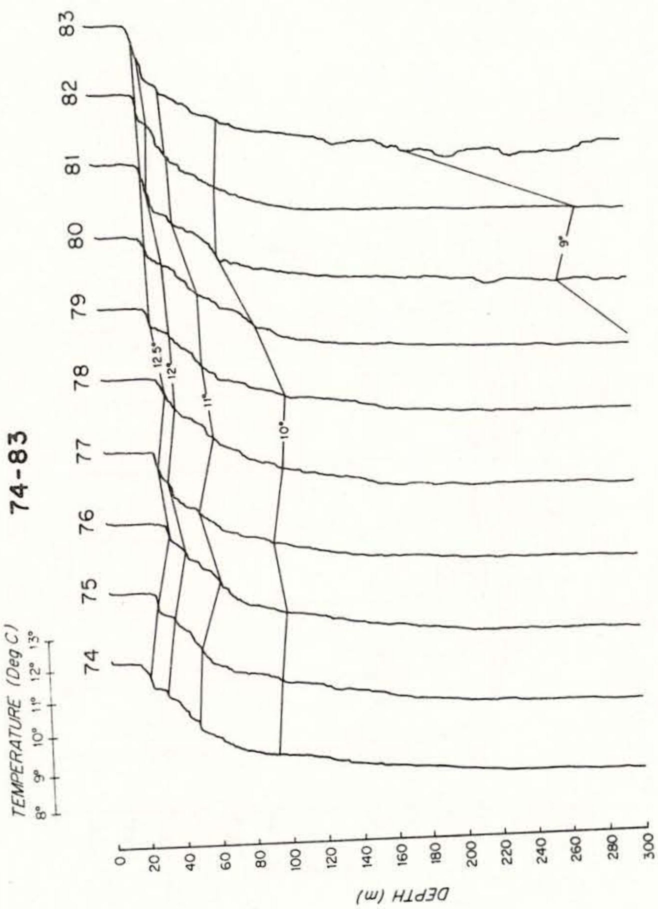
XBT Section 4.



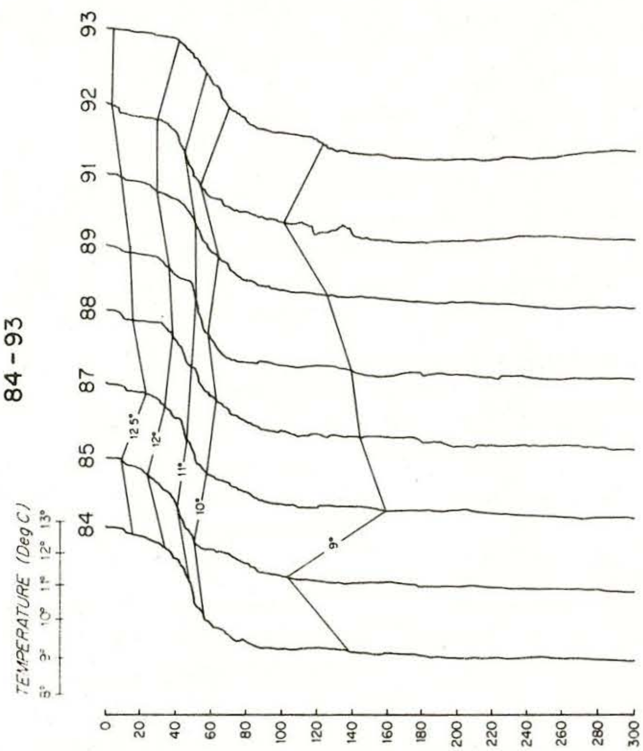
XBT Section 5.



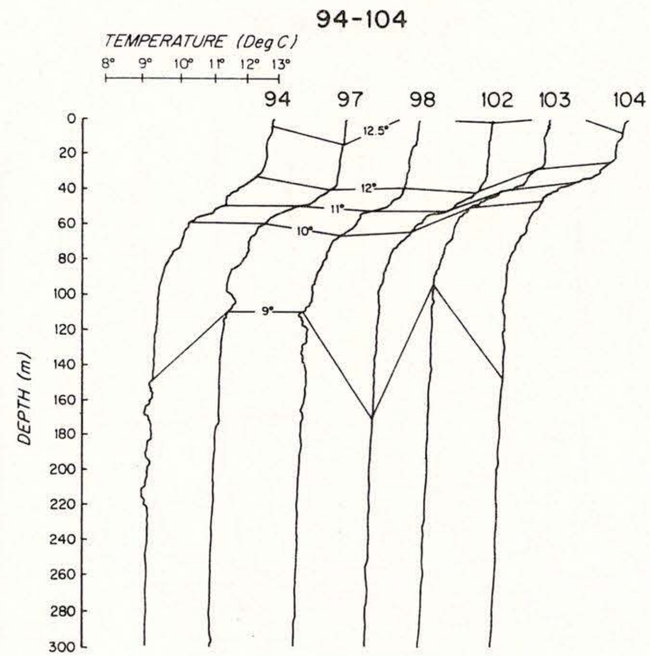
XBT Section 6.



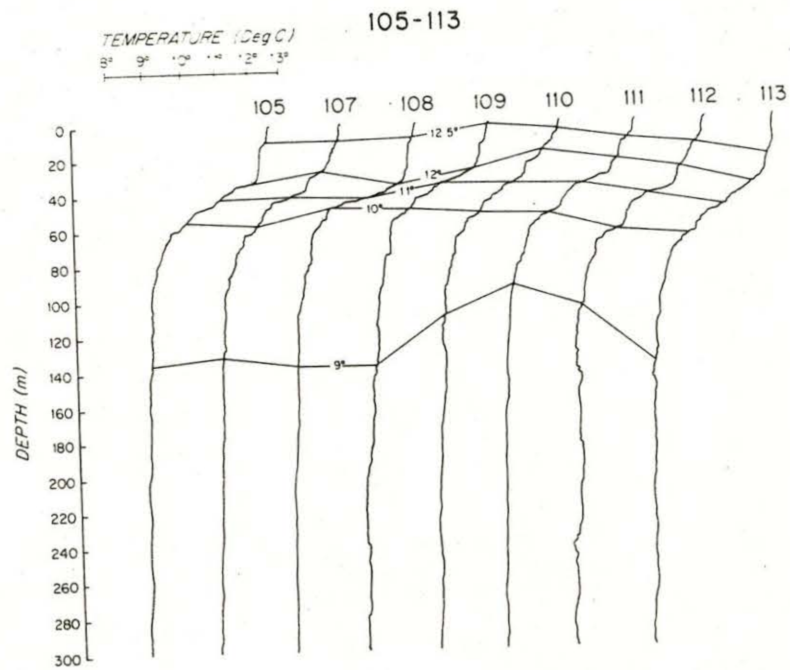
XBT Section 7.



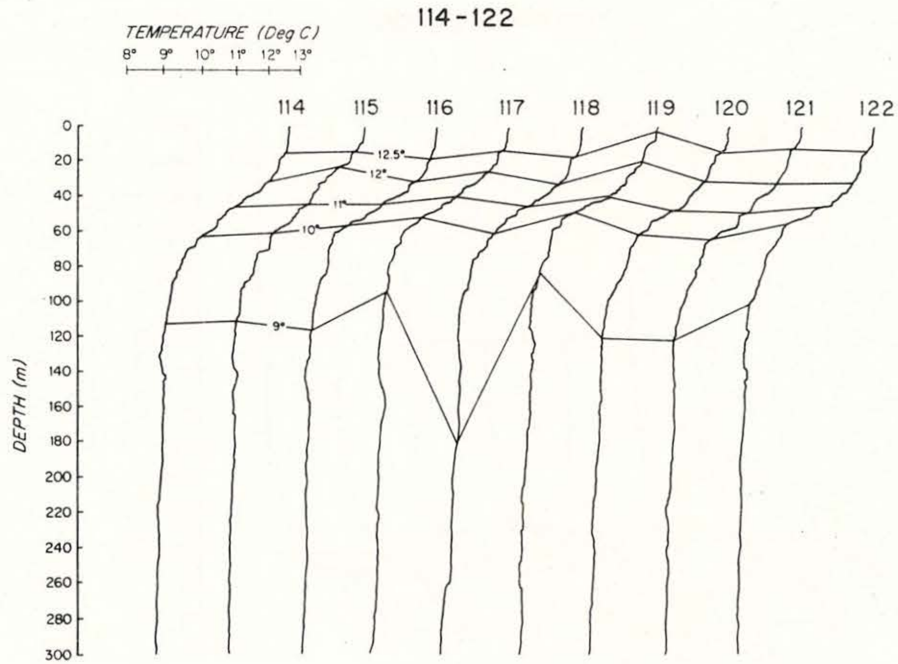
XBT Section 8.



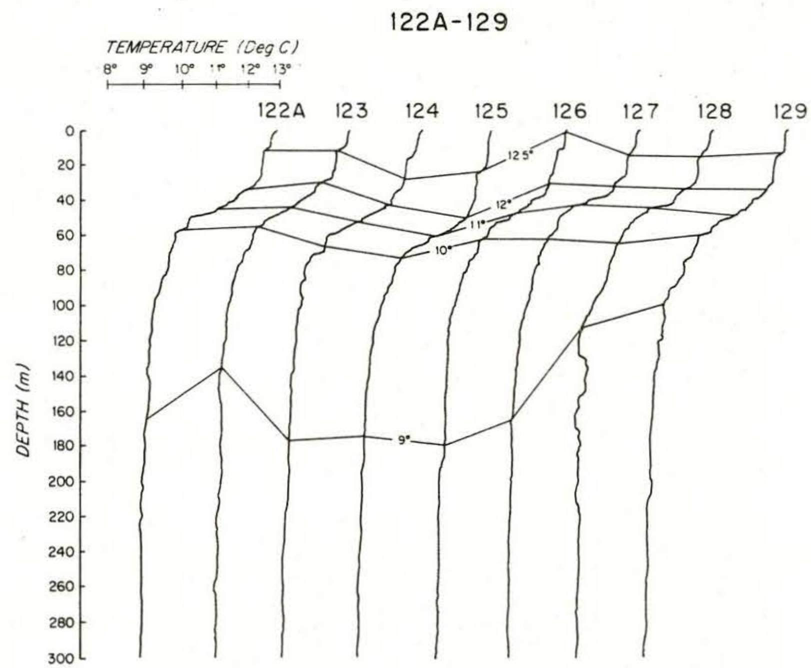
XBT Section 9.



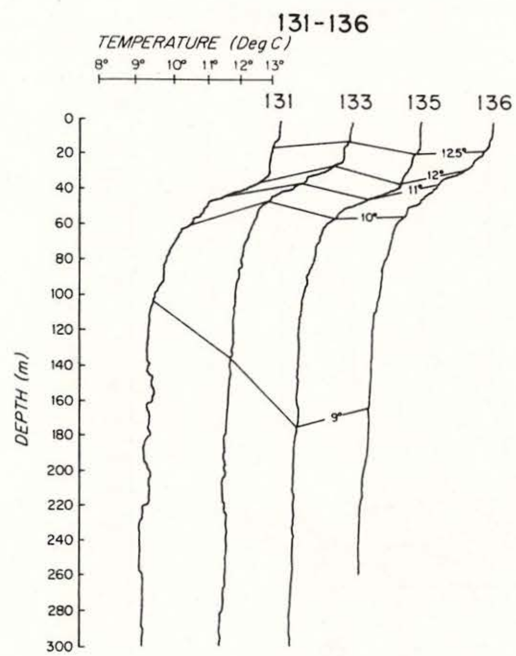
XBT Section 10.



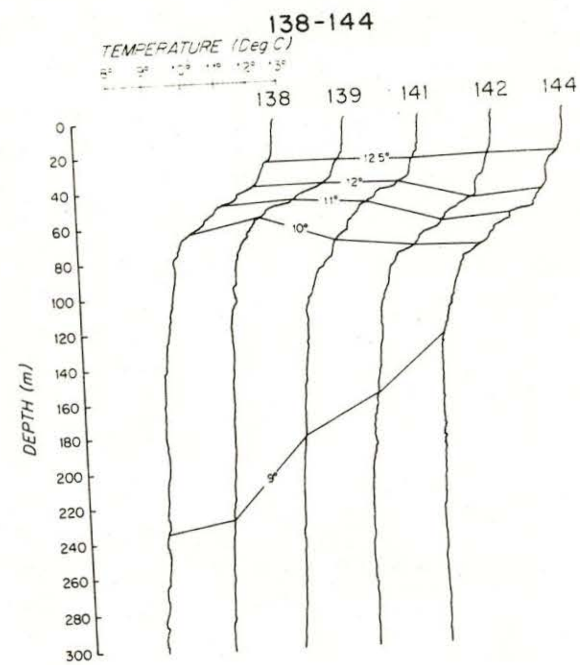
XBT Section 11.



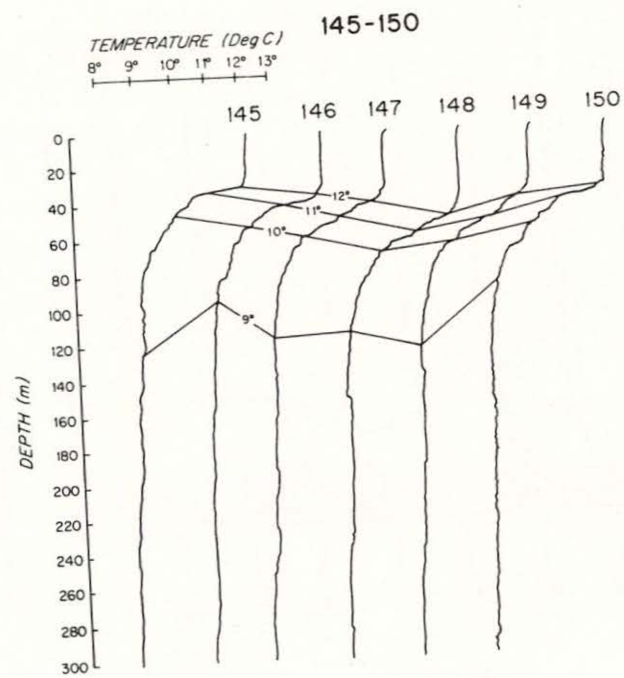
XBT Section 12.



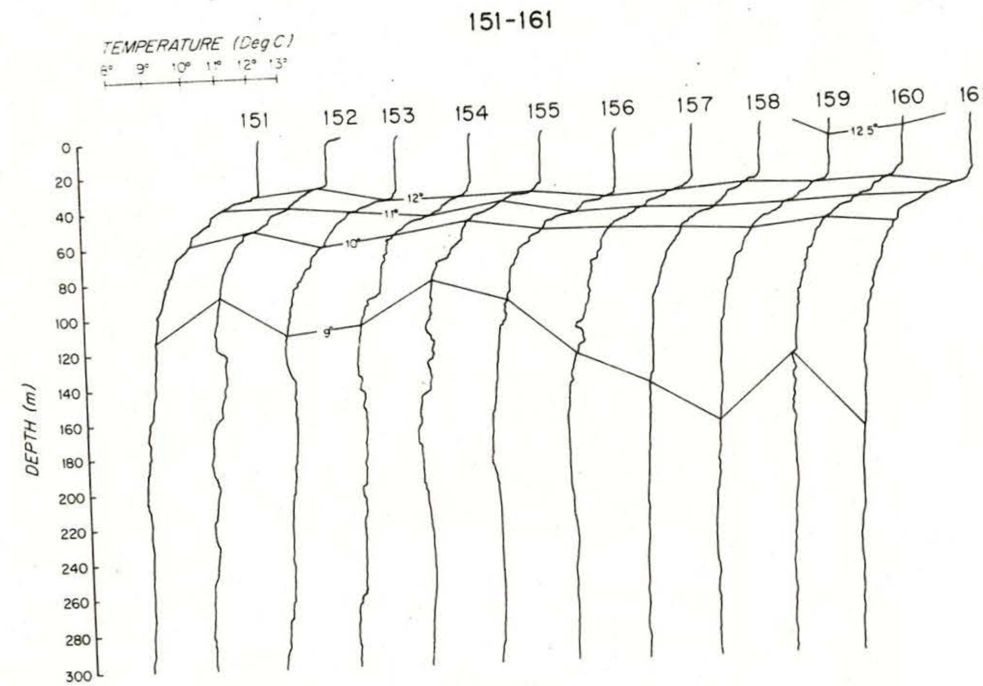
XBT Section 13.



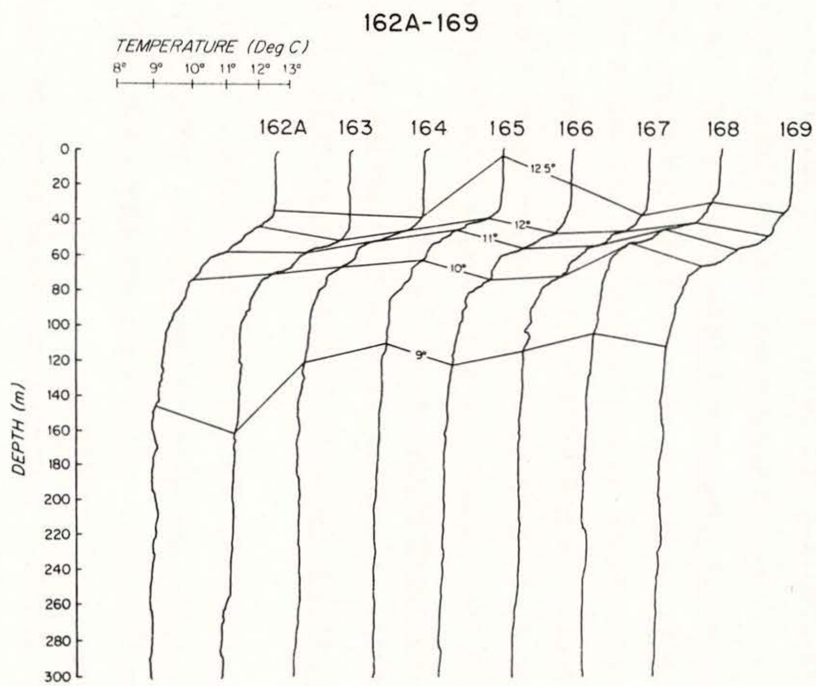
XBT Section 14.



XBT Section 15.



XBT Section 16.



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3. Temperature data

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